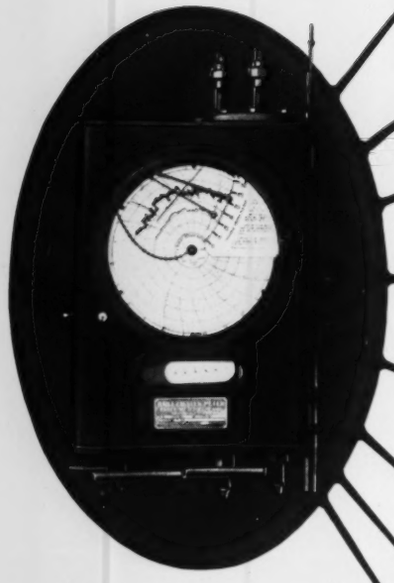
MECHANICAL
ENGINEERING
November 1935

EIGHT DIVIDENDS . .
ONE BOILER METER



1 On boilers of 100 h. p. or larger, the Bailey Boiler Meter produces a notable saving in fuel by guiding the way to best combustion efficiency.

2 Deterioration of furnace wall refractories is decreased, since excessive furnace temperatures are prevented.

3 Boiler capacity increases, thereby postponing and sometimes eliminating the necessity of enlarging the plant.

4 One Bailey Boiler Meter fills a threefold need . . . it is a Combustion Guide, a Steam Flow Meter, and a Flue Gas Temperature Recorder.

5 All records are made on a single uniformly graduated chart permitting easy, timesaving comparisons of related factors.

6 The meter tells when the boiler should be cut out of service for tube cleaning or repairing of the baffles.

7 Reliable data and permanent records are furnished for the Cost Accounting System.

8 Each Bailey Boiler Meter is designed to fit the particular installation to assure maximum effectiveness.

These dividends may amount to hundreds of dollars yearly in your plant. Write for bulletin No. 43a, which gives examples of actual savings made by the installation of Bailey Boiler Meters.

BAILEY METERS

D-7

BAILEY METER CO.

1026 IVANHOE ROAD CLEVELAND, OHIO.

Bailey Meter Company Limited, Montreal, Canada

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers

VOLUME 57 NUMBER 11

Contents for November, 1935

WORK ASSIGNMENT IN SILK AND RAYON MANUFACTURING	*L. P. Alford*	679
REFLECTIONS	*O. P. Hood*	685
EFFECT OF INSULATION	*D. G. Williams*	687
ATMOSPHERIC AIR	*W. L. DeBaufre*	691
UNDERFEED-STOKER PRACTICE IN GREAT BRITAIN	*W. M. Dodds*	695
SEPARATION OF RADIATION AND CONVECTION HEAT LOSSES	*Sydney Steele*	700
STEAM-TURBINE TESTING	*C. H. Berry*	705
THE THIRD INTERNATIONAL CONFERENCE ON STEAM TABLES		710
OUR INTERNATIONAL ACCOUNTS	*R. E. Freeman*	714
A.S.M.E. COMPLETING PLANS FOR 1935 ANNUAL MEETING		738

EDITORIAL	677	A.S.M.E. BOILER CODE	733
ENGINEERING PROGRESS	716	REVIEWS OF BOOKS	734
LETTERS AND COMMENT	726	WHAT'S GOING ON	738

DISPLAY ADVERTISEMENTS	1	PROFESSIONAL SERVICE	27
WHAT'S NEW	12	CLASSIFIED ADVERTISEMENTS	28
INDEX TO ADVERTISERS	30		

OFFICERS OF THE SOCIETY:

RALPH E. FLANDERS, *President*

ERIK OBERG, *Treasurer* C. E. DAVIES, *Secretary*

PUBLICATION STAFF:

GEORGE A. STETSON, *Editor* FREDERICK LASK, *Advertising Mgr.*

COMMITTEE ON PUBLICATIONS:

S. W. DUDLEY, *Chairman*

S. F. VOORHEES W. F. RYAN

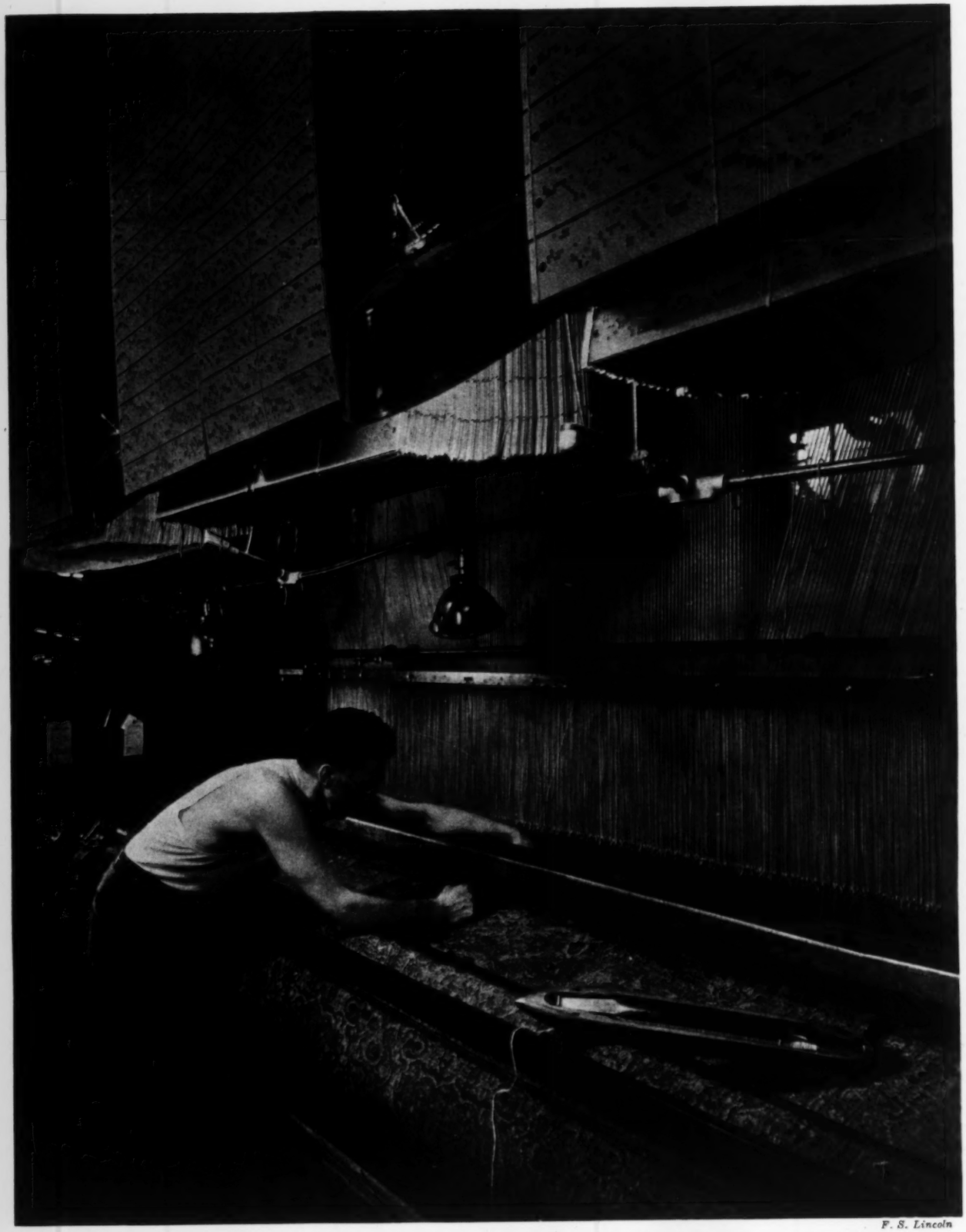
G. F. BATEMAN M. H. ROBERTS

ADVISORY MEMBERS OF THE COMMITTEE ON PUBLICATIONS:

E. L. OHLE, ST. LOUIS, MO. E. B. NORRIS, BLACKSBURG, VA. A. J. DICKIE, SAN FRANCISCO, CAL.

Junior Member, O. B. SCHIER, 2D

Published monthly by The American Society of Mechanical Engineers. Publication office at 20th and Northampton Streets, Easton, Pa. Editorial and Advertising departments at the headquarters of the Society, 29 West Thirty-Ninth Street, New York, N. Y. Cable address, "Dynamic," New York. Price 60 cents a copy, $5.00 a year; to members and affiliates, 50 cents a copy, $4.00 a year. Postage to Canada, 75 cents additional, to foreign countries, $1.50 additional. Changes of address must be received at Society headquarters two weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Law: The Society shall not be responsible for statements or opinions advanced in papers or . . . printed in its publications (B2, Par. 3). . . . Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879. . . . Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921. . . . Copyrighted, 1935, by The American Society of Mechanical Engineers.



F. S. Lincoln

Carpet Loom, Gulistan Mills

VOLUME 57
No. 11

MECHANICAL ENGINEERING

NOVEMBER
1935

GEORGE A. STETSON, *Editor*

Who Knew Westinghouse?

AROUND all great and well-known characters there grows up a wealth of anecdote and legend in which the personalities of men are shown in familiar and frequently very human ways. But unless some one takes the trouble to record these stories they die out as men's memories grow dim, or they take on the preposterous proportions of caricature. To be of value they must be collected, edited, and preserved by the zeal and devotion of some one familiar enough with the individual to feel a responsibility for the authenticity of the stories.

Charles F. Scott is engaged in collecting anecdotes about his former employer, George Westinghouse, past-president and honorary member of The American Society of Mechanical Engineers, whose biography, by Henry G. Prout, the Society published in 1921. Professor Scott will be grateful to those who knew George Westinghouse and have cherished stories about him.

The Village Hampden—New Style

THAT incensed stockholder who announced at the meeting of the Electric Bond and Share Company that he would be willing to shoulder a gun in defense of the properties represented by his securities may not go down in history with dozens of other citizens of all ages who have fought for their property, but he is typical of a growing class of embittered protestants that find themselves fighting for ancient liberties dressed up in modern fashion. The world has accorded approval and acclaim to the embattled farmers of Concord who "gave the Redcoats ball for ball" in defense of their stone-walled fields and pastures. The modern version of that "village Hampden, that with dauntless breast the little tyrant of his fields withstood" will substitute the word "bonds" for "fields," and with good reason. For as Olin Ingraham pointed out in MECHANICAL ENGINEERING a couple of months ago scraps of paper are what the citizen of today lays up for his old age. "Paternal acres" have given place to the safe-deposit box and an infinitesimal part ownership in stocks and bonds held in the individual's name by some insurance or trust company.

We probably shall not see the mobilization of the "Utility Fusilleers," ready to fight at the drop of a quotation, because, through the ballot box the defenses against modern property are most effectively made, but popular and widespread approval of the inherent right of a man to resist usurption of what he has acquired as the fruit of his labors is bound to increase. Indeed, the time may come when the sacredness of these modern forms of property will stir the time-honored emotions that used to kindle, in former ages, when men defended their flocks and their firesides.

One of the changes in viewpoint that has been creeping over western people during recent generations has been that which has come into our mores with respect to this form of proprietorship. For generations to come, without doubt, it will be unwise and unsatisfactory to trust to government guaranteed security in the way of unemployment "insurance" and old-age pensions. Many are estopped from enjoying the beneficence of this governmental largess by serving what the law is pleased to term "non-profit" organizations; while others find themselves, under the present old-age security legislation, restricted to the enjoyment, beyond age 65, of a monthly stipend of $85 after 45 years of service. Much still depends on the integrity and liquidity of the investments engineers make on their own initiative in the securities of the nation's industries. During their working years engineers find employment, largely, in the companies that stand back of these scraps of paper. In their old age they must continue to look to them for what measure of economic security they are to enjoy.

An Undeserved Blot

IT DOES not take wars abroad, protestations of neutrality, and pious words about being a peace-loving nation to remind us of the wastefulness of wars at home. For these wars abroad we profess abhorrence, but for the privilege of conducting industrial wars at home we stand stubbornly and foolishly steadfast. Suspicion and misunderstanding that stand between employer and employee when technological techniques, such as the much talked of stretch-out in the textile industry, are installed, defeat the common social and economic gains that should be a blessing to both parties. The very existence of great mills, employing hundreds of trained workers, is jeopardized in many cases when management and labor fail to see eye to eye or attempt to insist on some imagined advantage secured at the expense of others. Industrial strife, with its wastefulness and bitterness, wrecks the honest intentions of both sides and frequently ends in bankruptcy and misery.

MECHANICAL ENGINEERING has twice before informed its readers on phases of the perplexing problem of the stretch-out in papers by Elliott Dunlap Smith and Raymond C. Nyman. National interest in the problem was aroused last summer in the report of the Winant board, appointed by the President to look into conditions in the textile industry. As a result of this report, four work-assignment boards were set up and factual studies were made in the major branches of the industry. Fortunately for the silk and rayon industry, its work-assignment board included an engineer of proved ability and unusual fitness for such a research, L. P. Alford, first Melville Medalist of The American Society of Mechanical Engineers. From the report of this board Mr. Alford has prepared a résumé that is published as the leading article in this issue and that will be presented at the 1935 Annual Meeting. It is an interesting document, not only to the textile industry but to all engineers who have had faith in industrial management.

In addition to the technicalities that will be most valuable to men in the industry, two conclusions which Mr. Alford reaches deserve emphasis. They are to the effect that in the silk and rayon textile industries the principles and practice of industrial engineering, as understood and applied by members of the A.S.M.E., are unknown and unapplied. Mr. Alford points out that industrial engineers are condemned "because of the popular belief that the discoveries they have made are being used to oppress workers . . . . . Such charges," he continues, "require of industrial engineers that they should reexamine their practices to make sure that they are discharging their full professional and societal obligations. No engineer should be party to fixing a work assignment which requires excessive effort to perform, nor to the setting of a wage rate which is inequitable for the work to be done and the effort to be expended."

Those who feel that engineers no longer have opportunities for industrial and even social service should ponder these words. There is opportunity to remove an undeserved blot on the escutcheon of engineering in this and in other industries.

December 2 to 6, 1935

LAST month MECHANICAL ENGINEERING carried a story of the truly remarkable Machine Tool Show held at Cleveland. Among the many words uttered in praise of this event those most frequently heard were for the courage, initiative, and optimism of the machine-tool industry. A fine example of determination and progress was set by this industry, and engineers should not be afraid or unwilling to follow it.

From December 2 to 6 of this year The American Society of Mechanical Engineers will hold its Fifty-Sixth Annual Meeting. A foretaste of what is in store for those who attend has been set forth on pages 738 to 741 of this issue. For months individuals, committees, and professional divisions have been hard at work on programs, papers, and arrangements. With an enthusiastic participation by every member who can get to New York, this year's meeting should mark the Society's entrance upon a new era of useful service and purposeful progress. The times are ripe for it.

During October and November, matters of Society policy and planning will have been discussed at group conferences of delegates of A.S.M.E. local sections at seven convenient centers over the United States. Reports of committees covering the year 1934–1935 have been printed for use at these meetings and will be distributed to every member as the second section of the November Transactions. There will be no excuse for members not knowing what has been going on and what plans are being laid. Through the conferences, which will send delegates to New York for the meeting in December, every one will have a chance to be represented even if he himself cannot be present in person. Through the publications the technical papers will also reach all members; many of them have been preprinted. The elements of success are present; all that is now needed is live interest and enthusiastic cooperation.

The profession and the Society face an undoubted era of activity and progress. Business is coming back. Engineers, suffering from lack of employment, are being reemployed. Registrations in engineering colleges are up—an evidence that youth, at least, has courage and optimism. The hard lessons of dull times have been learned and a determination to avoid the mistakes of the past and to embrace the opportunities of the future is strengthening the morale of the Society.

What are the opportunities of the future? Greater, we predict, than those whose realization made the past such a credit to the profession. We can promise that President Flanders' address "New Pioneers on a New Frontier," to be delivered at the Annual Dinner on December 4, will be full of them, for, although we have not seen his script, we know the caliber of his wise and courageous philosophy from his past utterances.

The national economy has taken such a definite trend that the place of the engineer in it will be one of even greater importance than in the past. For without technological advance and managerial skill future progress will be impossible and stagnation and confusion will result. The keynote will be in reduced costs, obtainable most equitably from a social and economic standpoint from the contributions that engineers can best make. That this will require higher types of individuals than have made up the profession in the past is undoubted. To attract and train men of greater caliber is the joint responsibility of the engineering school and the engineering society. There is ample evidence that the engineering schools are alive to their opportunity and their responsibility. Engineering societies must become conscious of theirs, and coordinate their activities and lay their plans to this end.

At the dawn of this era of new pioneers on new frontiers a revival of common interests and purposes can gather headway under the stimulation derived from the Annual Meeting. Make it a point to be there. The dates are December 2 to 6, 1935.

Work Assignment in SILK *and* RAYON MANUFACTURING

By L. P. ALFORD

CONSULTING ENGINEER, NEW YORK, N. Y.

STRETCH-OUT, specialization, work assignment, or the introduction of labor-saving methods was one of the four fundamental issues in the nation-wide textile strike of August and September, 1934, in the United States. The other three major factors were: Recognition of the union and methods of collective bargaining; machinery for handling complaints of violation of section 7(*a*) and other labor provisions of the NRA codes of fair practice; hours and wages.

The problem of stretch-out is essentially one of industrial management. The board of inquiry for the cotton textile industry, under the chairmanship of Governor John G. Winant, reported in part as follows:

> The so-called "stretch-out" system is essentially the introduction of labor-saving methods into the various processes of the textile industry. The introduction of the stretch-out system may accompany the introduction of new machinery; but the stretch-out is not necessarily related to the introduction of labor-saving machinery. Adoption of the stretch-out system does not necessarily increase the work load of the individual worker; but if not done scientifically it results in most cases in an additional burden on the employee.
>
> Exploitation of the worker through introduction of the stretch-out system does not necessarily result from the mere increase in the number of looms or other machines the worker is called upon to tend. Whether the stretch-out results in exploitation depends upon numerous complicated factors such as the number of machines the worker must operate, the division of labor in operating those machines, the physical conditions under which the employee works, the character of the machine, the quality of the yarn, and like factors.
>
> The problem in regulating the use of the stretch-out system is to find the proper balance between the fullest possible utilization of devices that will result in increased efficiency and at the same time protection to the worker from improper increase in work load. The problem is difficult because of the numerous and often incalculable factors that must be taken into consideration in reaching the proper result.

To deal with the situation portrayed by the Winant report, and following its general recommendations for settling the strike, a plan was put into effect by a group of presidential orders, and certain amendments to the codes of fair practice for the several branches of the textile industry. The principal actions taken in regard to stretch-out or work assignment are these:

> The Textile Labor Relations Board shall appoint a single individual as common chairman of the Cotton Textile Work Assignment Board, the Silk Textile Work Assignment Board, and the Wool Textile Work Assignment Board.
>
> The cotton, silk, and wool work assignment boards shall study the actual operation of the stretch-out (or specialization) system in a number of representative plants, including such plants as may be selected respectively by the code authority affected and by the United Textile Workers of America and such other plants as the boards may themselves select either upon or without nomination of interested parties. The boards shall, after consultation with the employers and employees in the respective industries, and their representatives, prepare, and before January 1, 1935, submit to the President, recommendations for a permanent plan for regulation of work assignments in the respective industries.

An amendment to the code of fair practice for the silk textile industry, article 13, has this provision:

> In order to provide opportunity to develop a sound method and adequate organization for the regulation of work assignments, no employer prior to February 1, 1935, shall make any change in work assignment of any class of employees which shall increase the effort required over that prevailing on September 21, 1934.

The presidential order from which the foregoing requirements are quoted was dated October 16, 1934. The several boards were constituted during the succeeding weeks of the year. The members of the steel labor board became the textile labor board under the chairmanship of Judge Walter P. Stacy. The common chairman of the work-assignment boards was W. A. Mitchell. The members of the silk-textile-work assignment board were E. L. Oliver, employee representative, and J. W. Nickerson, employer representative.

An engineering research staff was organized under the silk board consisting of Norman P. Cubberly, S. A. Hazen, C. C. Jessop, H. P. Losely, J. A. Piacitelli, and the author of this paper as chief engineer. Only the personnel of the silk board and its research staff is given for the reason that this paper is restricted to a consideration of work assignment in the silk and rayon textile industry.

The several textile work-assignment boards ceased to exist on June 16, 1935, and were disbanded with the ending of the National Industrial Recovery Act. Previous to this date each board had reported a plan for a permanent organization of its industry. No action has been taken upon these recommendations (September, 1935).

Appreciation is gratefully extended to Messrs. Nickerson and Oliver, and to the engineers of the research staff, for the work which made this paper possible. The investigation was truly cooperative and credit should be given to the group as a whole for whatever is constructive in the findings and results. For the method of presentation the author is solely responsible.

Acknowledgment is also due, and is appreciatively given, to H. J. Bickford for constructive criticism and helpful suggestion.

Recognition is also acknowledged of the cooperation of officials, executives, and operators of the mills in which investigations were made, and of the assistance of union-labor officials in the localities of these mills. Without this cooperation and assistance the studies could not have been conducted as expeditiously and thoroughly as was done.

The technical work delegated to the research staff was to study work assignments in silk and rayon mills, to investigate complaints of stretch-out and excessive work assignments, to investigate changes in work assignment asked for in petitions from employers requesting authority to make such changes,

Contributed by the Management and Textile Divisions for presentation at the Annual Meeting, New York, N. Y., Dec. 2-6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

and to formulate a method of judging the reasonableness of the work effort required in any silk or rayon mill. A more comprehensive objective, though one less capable of precise definition, was to aid in improving industrial relations for the benefit of employers and employees alike.

Studies were made in 30 silk and rayon mills located over a wide area in the states of Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, and Ohio. In size they ranged from some of the largest to others among the smallest concerns in the industry. As most of the investigations were made on weaving, this paper is restricted to a consideration of work assignment on silk and rayon weaving operations.

Emphasis should be placed upon the attitude of the members of the research staff which prevailed throughout the investigations. No effort was made to improve any process or operation, to shorten the time of performance, or to lower costs. Rather, the purpose was to secure creditable facts from which conclusions might be drawn. In this respect the work done was in sharp contrast to the usual industrial-engineering survey.

The results of the research work, apart from the determination of immediate questions at issue under complaints and petitions, were the formulation of a theory and principle of a reasonable work assignment, development of a method of judging the reasonableness of a work assignment that has been set, and a determination of times for elementary weaving operations on two classes of silk fabrics and one class of rayon fabrics. These industrial-management findings are given in this paper. They are supplemented by a formula for determining a loom assignment, and recommendations as to free-time allowances. These latter findings were not in the report of the research staff for the reason that they were judged to be matters without the scope of the investigation. They are included here to round out a presentation of work assignment.

In any consideration or application of these results one caution must be kept in mind. The Silk-Textile Work-Assignment Board accepted the findings of the research staff as indicating strongly that a set of principles and a technique for establishing a work assignment could be formulated and developed. However, these findings must be applied carefully in any local situation; the silk textile industry is so large and its conditions are so varied as to place a limitation on the results, both as standards and as to the relation of one factor with another. That is, the data hereafter presented should be used only with considerable checking under the local conditions where they are applied.

Before presenting these several findings certain further comments are advisable in order to give a background against which the technical results are to be judged.

Methods of work assignment based on time study were found by the research staff in only three of the mills investigated. In one of these the work assignment was based on the estimated "actual working time" of the weaver, in the others on an estimated operating efficiency of the looms. The prevailing practice appears to be to assign arbitrarily a certain number of looms to a weaver on "judgment," "experience," market conditions, or by guess. Often these decisions are made in the home office far away from the mill.

The investigations made on complaints of stretch-out, or excessive work assignment, either showed or created a strong surmise that a wage situation was the real occasion for the filing of the complaint. The issues as they were formulated had to do with increases or changes in work assignments. Actually they were symptoms of other situations more vital to the operators. Among these "other situations" were disadvantageous changes in piece rates, the necessity of increased effort to earn a satisfactory wage, a feeling that the wage earned was too little, and a belief that there was no true relationship between the effort demanded and the wages paid. The fear that acceptance of an increased loom assignment might throw another weaver out of work, with a consequent loss of earnings, was also given as a reason for filing certain of the complaints.

The general conclusion in regard to work assignment which was cumulatively forced by the several studies is:

A proper work assignment is an amount of work that can be performed with a reasonable expenditure of effort in a period of time mutually satisfactory to worker and management, and the accompanying remuneration must be equitable and agreeable for the work performed and the effort expended. The three factors, (1) amount of work done, (2) the time during which it is to be performed, and (3) the wages paid therefor, are positively interrelated. No equitable and lasting decision can be made concerning any one of these factors without giving due consideration to the other two.

PRINCIPLE OF WORK ASSIGNMENT

For the purpose of the investigation the following definition of work assignment was adopted:

"The amount of work allotted to be performed in a specified time."

The principle of reasonable work assignment was declared to be:

"A reasonable work assignment is an amount of work to be done in a given time, for a wage mutually satisfactory to worker and management, and capable of being performed by a worker of average skill in the time specified with an amount of free time sufficient for personal needs and the relief of fatigue."

METHOD OF JUDGING A WORK ASSIGNMENT

From the foregoing principle of work assignment it follows that the method of judging a work assignment must take into account nine cases, or combinations, of amount of work done and free time. These cases group into three classes when the work accomplishment is used as the control factor.

Cases 1, 2, and 3: Work accomplishment is equal to the work assignment; free time is equal to, greater than, or less than the standard.

Cases 4, 5, and 6: Work accomplishment is less than the work assignment; free time is equal to, greater than, or less than the standard.

Cases 7, 8, and 9: Work accomplishment is greater than the work assignment; free time is equal to, greater than, or less than the standard.

On nearly every weaving job the actual work accomplishment will be either greater or less than the amount specified in the work assignment. Thus rule 2, which follows, is the one which will usually apply. Rule 1 is included to complete the analysis of all nine cases, but without the expectation that it will be often, if ever, applied.

Rule 1: If the amount of work done is equal to the amount specified in the work assignment, as in cases 1, 2, and 3, standard times shall be calculated for the number of occurrences observed. If the amount of free time so determined is equal to, or greater than, the standard, the work assignment shall be judged to be reasonable. If the amount of free time so determined is less than the standard, the work assignment shall be judged to be excessive.

Rule 2: If the work done is less than, or greater than, the amount specified in the work assignment, as in cases 4 to 9, the number of occurrences that would have prevailed, if the actual work done had been equal to the work assignment, shall

be computed. Standard times shall then be calculated for the number of occurrences as computed for the specified work assignment. If the amount of free time so determined is equal to, or greater than, the standard, the work assignment shall be judged to be reasonable. If the amount of free time so determined is less than the standard, the work assignment shall be judged to be excessive.

STANDARD TIMES FOR SILK AND RAYON WEAVING

To apply these two rules it is necessary to establish standard times for elementary operations. When the research staff began its work it was unsuccessful in finding a satisfactory classification and acceptable definitions of the elementary operations in silk weaving. We therefore developed them for our own use. Appendix 1 gives a schedule of 25 elementary operations in silk and rayon weaving, with a definition for each.

These elementary operations group as follows:

Work while loom is stopped

1 Warp break in front of loom
2 Warp break in back of loom
3 Break by weaver
4 Warp defect
5 Twisted warp break
6 Missing warp thread
7 Pick out
8 Filling break
9 Change shuttle
10 Shuttle runout
11 Change and fill shuttle
19 Miscellaneous work while loom is stopped
22 Doff cut of cloth
23 Loom fixing
25 Bang-off

Work while loom is running

12 Fill spare shuttle or fill magazine
13 Strip quill
20 Miscellaneous work while loom is running
21 Preposition quill
24 Take up spare ends

Patrolling, walking, and examining

14 Walk to give attention
15 Examine work or loom
16 Patrolling

Free time

17 Personal needs
18 Inactive time

For the purpose of setting standard elementary times broad silk fabrics were divided into seven classes: Gum silk, plain; gum silk, satin; plain taffeta, twill; soft silk; fancy, 10-shaft or more; canton crepe; and sheer.

Rayon fabrics were similarly grouped into five classes: Rayon acetate, plain; rayon acetate, satin; fancy, 10-shaft or more; canton crepe; and sheer.

Sufficient time-study information was secured to set creditable standards for three of these classes: Gum silk, plain; gum silk, satin; rayon acetate, plain. These times are given in Table 1. It appears that these times are the first instance of an attempt to set standard times applicable to an entire industry.

The times given in Table 1 are based on composite information; that is, data were combined from all the mills where time studies were made. Where it was possible to compute a modal average that value is given in the table. Where the nature of the observed data did not permit the determination of the mode, the arithmetic mean was calculated and used. Items 14, 15, and 16 are not true elementary operations, but each can be expressed as a function of a group of elementary operations. Figs. 1, 2, and 3 give these relations.

TABLE 1 ELEMENTARY TIMES FOR SILK AND RAYON WEAVING

(Based on modal averages where possible, arithmetic means elsewhere)

		Time in minutes		
		Gum silk		Rayon acetate
	Occurrence	Plain[a]	Satin	plain
1	Warp break in front of loom	0.88	0.91	0.74
2	Warp break in back of loom	1.08	1.21	0.97
3	Break by weaver	0.83	0.83	1.05
4	Defect front and back	0.19	0.59	0.66
5	Twisted warp break	0.50	0.58	....
6	Tie back	1.10	1.10	1.45
7	Pickout	....	....	....
8	Filling break	0.28	0.57	0.37
9	Change shuttle	0.10	0.11	0.11
10	Shuttle runout (spare)	0.67	0.67	0.75
	Shuttle runout (no spare)	....	....	1.35
11	Change and fill shuttle	0.34	0.34	0.34
12	Fill spare shuttle	0.25	0.25	0.21
	Fill spare shuttle and load magazine	....	....	0.25
	Place quill in magazine	....	....	0.09
13	Strip quill	0.10	0.10	0.06
14	Walk to give attention	(a function of work while stopped)		
15	Examine work and loom	(a function of total work)		
16	Patrolling	(a function of work while running)		
17	Personal needs	(a percentage of total time)		
18	Inactive time	(a percentage of total time)		
19	Miscellaneous work while stopped	....	....	....
20	Miscellaneous work while running	....	....	....
21	Preposition quill	0.10	0.10	0.10
22	Doff cut	....	....	....
23	Loom fixing	....	....	....
24	Take up spare end	0.19	0.19	0.18
25	Bang-off	0.07	0.07	0.07

[a] Less than 140 denier.

Fig. 1 plots the time of "walking to give attention" and the time of "work while loom is stopped," each in minutes per thousand picks thrown. Fig. 2 plots "examining" time in minutes per thousand picks thrown, and time of "total work" in minutes per thousand picks thrown. Fig. 3 plots the time of "patrolling," and time of "work while loom is running," each in minutes per thousand picks thrown.

For each of these charts it is believed that the shape of the curve is determined. It is unfortunate that the early termination of the work prevented the accumulation of more data to fix more closely the exact location of the curves. It is to be hoped that more research will be done on these three elements of work in weaving.

Two other items in the schedule of Table 1 require discussion. No values are given for No. 17 "personal needs" and for No. 18 "inactive time." Taken together these items make up the free time of the operator to be used for personal needs and for the relief of fatigue. The author offers as a minimum standard for free time in silk and rayon weaving 12½ per cent of the total time. This amounts to 60 min in a 480-min shift. As a matter of interest the median value of the free times found by the time studies of silk and rayon weaving was 59 min in 480 min.

NUMBER OF LOOMS PER WEAVER

Although the research staff did not report any method for determining a reasonable work assignment in advance, it did examine a number of formulas offered for this purpose. The one given here is modified slightly from what seems to be

the most direct and simplest of these various methodologies.

Two determinations are needed at the outset: The correct average amount of work which the weaver must do to produce 1000 picks of the fabric on which a work assignment is to be set; the standard allowance for free time.

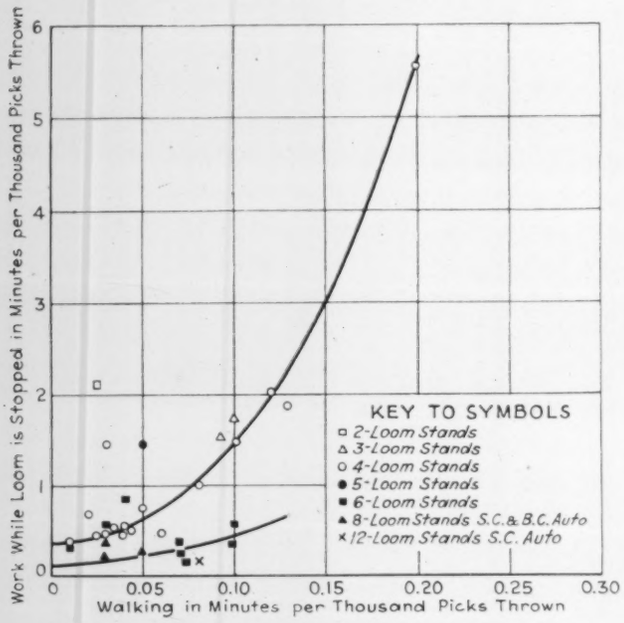

Work While Loom is Stopped in Minutes per Thousand Picks Thrown
Walking in Minutes per Thousand Picks Thrown
KEY TO SYMBOLS
2-Loom Stands
3-Loom Stands
4-Loom Stands
5-Loom Stands
6-Loom Stands
8-Loom Stands S.C.& B.C. Auto
12-Loom Stands S.C. Auto

FIG. 1 RELATION OF WALKING AND WORKING WHILE LOOM IS STOPPED

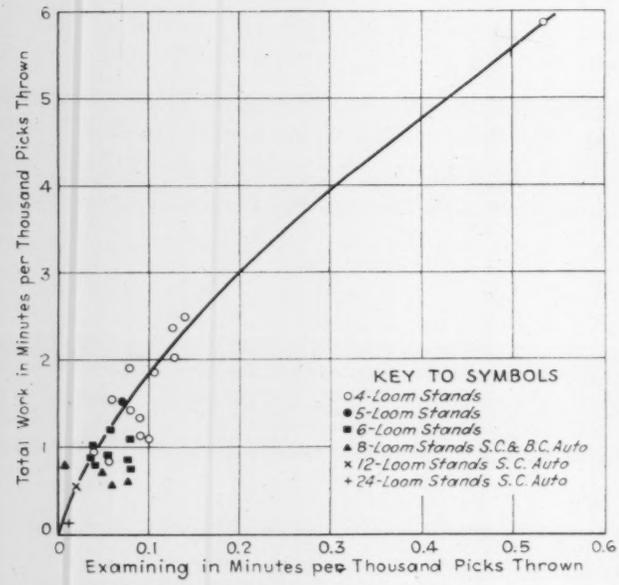

Total Work in Minutes per Thousand Picks Thrown
Examining in Minutes per Thousand Picks Thrown
KEY TO SYMBOLS
4-Loom Stands
5-Loom Stands
6-Loom Stands
8-Loom Stands S.C.& B.C. Auto
12-Loom Stands S.C. Auto
24-Loom Stands S.C. Auto

FIG. 2 RELATION OF EXAMINING AND TOTAL WORK

For any job, after the average number of minutes per 1000 picks produced and the free time allowance have been determined, the work assignment of the weaver in thousands of picks is readily established for the work day whatever its length. The formula is:

$$\text{Work assignment in thousands of picks} = \frac{\left[\text{Minutes per work day}\right] \times \left[1 - \frac{\text{Per cent of free time allowance}}{100}\right]}{\text{Total minutes of work per 1000 picks}}$$

Total minutes of work per 1000 picks includes the times for work while loom is stopped, while loom is running, walking to give attention, examining, and patrolling.

Example: Fabric, plain satin crepe.

Operation	Minutes
Work while loom is stopped	113.17
Work while loom is running	85.48
Walking to give attention	44.39
Examining	14.34
Patrolling	40.44
Total	297.82

The number of picks thrown is 249,000, and the minutes of total work per 1000 picks thrown is 297.82/249 = 1.195. Then the work assignment in thousands of picks per 8-hour day is 480(1 — 12.5/100) ÷ 1.195 = 351+. Therefore, the work assignment is 351,000 picks per 8-hour day.

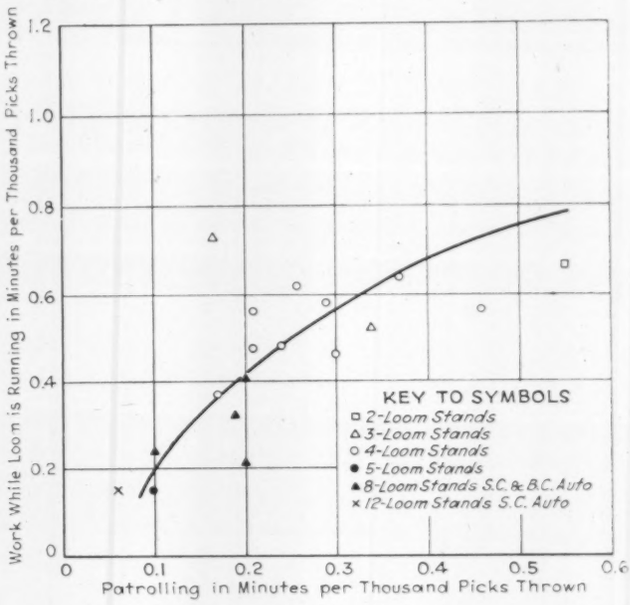

Work While Loom is Running in Minutes per Thousand Picks Thrown
Patrolling in Minutes per Thousand Picks Thrown
KEY TO SYMBOLS
2-Loom Stands
3-Loom Stands
4-Loom Stands
5-Loom Stands
8-Loom Stands S.C.& B.C. Auto
12-Loom Stands S.C. Auto

FIG. 3 RELATION OF PATROLLING AND WORK WHILE LOOM IS RUNNING

The piece rate for the job is readily set to give the weekly earnings which are "equitable and agreeable for the work performed and the effort expended." To continue the example, assume that this amount is $27 for a 5-day week of 40 hr. Hence the piece rate = 27 ÷ (351,000 × 5)/100,000 = $1.54 per 100,000 picks, or, say, $1.50 per 100,000 picks.

It is evident from this formula and example that the work assignment is fixed for the job, and the number of looms assigned to an operator, or the speed at which they run, may be altered, if necessary, to make it possible for the operator to produce the number of picks assigned with a satisfactory loom efficiency. In considering a change in loom speed, higher speeds usually, but not always, increase the amount of work per 1000 picks. The reason for this situation is that more warp and filling breaks usually occur at the higher speeds. Time studies are indicated whenever a change is made in loom speed to determine the effect.

After the work assignment has been established by the method given, the number of looms

the weaver is to operate can be determined by the following formula:

$$\text{Number of looms} = \frac{\text{Work assignment per work day in picks}}{\left[\begin{matrix}\text{Minutes}\\ \text{per work}\\ \text{day}\end{matrix}\right]\left[\begin{matrix}\text{Loom speed}\\ \text{in picks}\\ \text{per minute}\end{matrix}\right]\left[\dfrac{\text{Loom efficiency}}{100}\right]}$$

The number of minutes in a work day is, for example, $60 \times 8 = 480$ min for an 8-hour work day. The loom speed is the number of picks thrown by the loom in one minute of full operation. The loom efficiency is the percentage of the full work day that the loom actually runs. Excluded from the calculation is the stopped time for warps out, for twisting-in new warps, for repairs other than minor loom fixing, waiting for work, and prolonged absence of the weaver. Included in the calculation is an allowance for the time of interference.

Every weaving job requires that a certain amount of work must be performed while the loom is stopped. The total time required for a loom to produce 1000 picks is the time required to do necessary work upon the loom while it is stopped, plus the running time required by the loom to throw 1000 picks.

If a weaver is required to operate several looms simultaneously, an additional allowance must be made for interference time. Loom interference time is the time a loom is stopped (the stoppage having been caused by its own stop motions or by the weaver) waiting for attention by the weaver. It occurs when two or more looms in a stand are stopped simultaneously. Such stoppages are frequent in loom operation, and the time involved must be allowed for in calculating the number of looms to be assigned to a weaver, else he will be unable to perform the number of minutes of work specified in the work assignment. If the piece rate or wage rate is figured on the work assignment, as computed by the method which has been given previously in this paper, and the estimated loom efficiency is figured by a method which does not allow for interference time, the weaver's earnings will be less than the amount that has been estimated.

The time necessary to be allowed for interference varies with the skill and speed of the weaver, and with the number of looms in the stand. The greater the weaver's skill and speed the less the interference time; the more looms in the stand the greater the interference time. The correct allowance can best be determined by careful time study and analysis of a sufficient number of jobs to give a creditable finding. One of the large silk mills where investigations were conducted has made such a determination and has embodied the results in a chart, Fig. 4, which is included by permission. The allowances thus provided for have been demonstrated to be adequate by a long and extensive application.

Fig. 4 gives loom efficiency, expressed as a percentage of the possible maximum, that may be expected from loom stands of from two to nine looms, and for various hand-time percentages computed from the formula that will be found at the top of the next column.

$$\text{Hand time in per cent} = 100\,\frac{\text{Time for work while loom is stopped in minutes per 1000 picks}}{\left[\begin{matrix}\text{Time for work while}\\ \text{loom is stopped in}\\ \text{minutes per 1000 picks}\end{matrix}\right] + \left[\begin{matrix}\text{Machine time}\\ \text{in minutes per}\\ \text{1000 picks}\end{matrix}\right]}$$

The use of the formula is illustrated by the following example:

Assume for a plain silk crepe work assignment 351,000 picks, work day 480 min, loom speed 140 picks per min, time for work while stopped 0.454 min per 1000 picks, machine time 7.142 min per 1000 picks, hand time in per cent = $100[0.454/(0.454 + 7.142)] = 6$ per cent.

From this point on the solution is by approximation or a cut-and-try method. To continue the example:

Corresponding loom efficiency from Fig. 4 for an 8-loom stand is 85.5 per cent. By computation the number of looms is $351{,}000 \div [(480)(140)(85.5/100)] = 6.11$ looms.

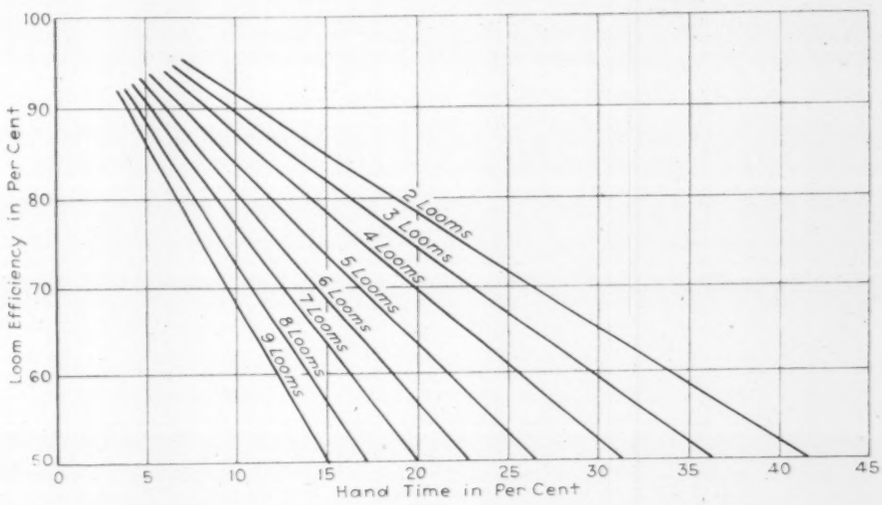


FIG. 4 RELATION OF HAND TIME AND LOOM EFFICIENCY IN SILK AND RAYON WEAVING

Corresponding loom efficiency from Fig. 4 for a 6-loom stand is 90.5 per cent. By computation the number of looms is $[351{,}000] \div [(480)(140)(90.5/100)] = 5.77$.

That is, a weaver should be able to operate six looms on the fabric specified at a loom efficiency of about 87 per cent and throw 351,000 picks in 8 hours, with $12\frac{1}{2}$ per cent of the total time free for personal needs and the relief of fatigue.

TWO GENERAL FINDINGS

The closing paragraphs of this paper revert to the major objective of the work of the research staff, "to aid in improving industrial relations for the benefit of employers and workers alike." Within the limitations of the studies two general findings are justified:

(1) With a few exceptions industrial engineering, as its principles and practice are understood and applied by the members of The American Society of Mechanical Engineers, appears to be unknown in the silk and rayon textile industry.

(2) With a few exceptions work assignments scientifically based on time studies, and interrelating time, product output, and wages, do not appear to be made in the silk and rayon textile industry.

Industrial engineers are condemned because of the popular belief that the discoveries they have made are being used to oppress workers. The agitation against the stretch-out is

evidence of this situation. Such charges require of industrial engineers that they should reexamine their practices to make sure that they are discharging their full professional and societal obligations. No engineer should be party to fixing a work assignment which requires excessive effort to perform, nor to the setting of a wage rate which is inequitable for the work to be done and the effort to be expended.

Let us not forget the policy of that great leader whose memory we delight to honor, Gantt, who would not install his system of management unless he was convinced that his client would not use the new scientific methods to oppress labor.

APPENDIX 1

ELEMENTARY OPERATIONS IN SILK AND RAYON WEAVING

1 *Warp break in front of loom.* Any warp break repaired by the weaver when he is standing in front of the loom.

(*a*) Record the number of threads repaired if more than one.

(*b*) Record more than five contiguous broken threads as a smash. Estimate the number.

(*c*) Record an excessive number of edge breaks separately.

2 *Warp breaks in back of loom.* Any warp break repaired by the weaver when he is standing in back of the loom.

(*a*) A break in a double warp thread is classed as a "twisted warp break."

(*b*) Record the number of threads repaired if more than one.

(*c*) Record more than five contiguous broken threads as a smash. Estimate the number.

(*d*) Record an excessive number of edge breaks separately.

3 *Break by weaver.* Any break made by the weaver whether in front or back of the loom.

(*a*) Record the number of threads repaired if more than one.

(*b*) Record more than five contiguous broken threads as a smash. Estimate the number.

4 *Defect.* Any defect in the warp that demands work by the weaver such as, tails, nibs, fuzz, and foreign substance.

5 *Twisted warp break.* Any break of a warp thread where two or more threads pass through a heddle, and the repair is made by twisting or tying the broken thread onto its mate or mates.

6 *Missing warp thread (tie back).* A missing warp thread which is replaced by an end taken from a spool.

7 *Pickout.* Unweaving because of a warp or filling defect.

(*a*) Record in minutes per inch for any pickout of more than ten picks. Smaller pickouts should be recorded as "shuttle runout" or "filling break."

8 *Filling break.* Any break in a filling thread.

(*a*) Time starts when weaver reaches for shuttle from in front of loom. Time stops when weaver pulls shipper handle.

9 *Change shuttle.* Replacing an exhausted shuttle.

(*b*) Time starts when weaver reaches for shuttle from in front of loom. Time stops when weaver pulls shipper handle.

10 *Shuttle runout.* Exhaustion of the filling leaving an uncompleted pick.

(*a*) Time starts when weaver reaches for shuttle from in front of loom. Time stops when weaver pulls shipper handle.

(*b*) Record absence of spare shuttle.

11 *Change and fill shuttle.* Reloading and replacing shuttle.

(*a*) Include clipping ends of filling.

(*b*) Record paper cops if used.

(*c*) Time starts when weaver reaches for shuttle from in front of loom. Time stops when weaver pulls shipper handle.

12 *Fill spare shuttle or fill magazine.* Reloading shuttle with quill or loading quill into magazine or loading shuttle into magazine.

(*a*) Record as fill spare shuttle, or fill magazine with quill or fill magazine with shuttles.

13 *Strip quill.* Removing unused filling from quill.

(*a*) Do not record if quill is stripped during watching or patrolling.

14 *Walk to give attention.* Includes walking to give any kind of specific attention to a loom.

15 *Examine work or loom.* Definite examination of work or loom by the weaver when he is in a stationary position.

16 *Patrolling.* Walking around the looms and watching their operation, to anticipate and to prevent occurrences.

17 *Personal needs.* Includes time for drinking and going to the toilet.

(*a*) Report in minutes, and as a percentage of the total time.

(*b*) When no lunch hour recess is provided, report the time taken for eating separately in minutes and as a percentage of the total time.

18 *Inactive time.* Includes free time when weaver is not working.

(*a*) Report in minutes, and as a percentage of the total time.

19 *Miscellaneous work while loom is stopped.* Include and specify any operations which occur while the loom is stopped and which are not elsewhere classified.

20 *Miscellaneous work while loom is running.* Include and specify any operations which occur while the loom is running and which are not elsewhere classified.

21 *Preposition quill.* Taking quill from rack preparatory to loading shuttle.

(*a*) Record the time for this operation when it is the habitual practice of the weaver.

22 *Doff cut of cloth.* Operation of removing a cut of woven cloth and rethreading the cloth around the take-up roll.

(*a*) Record separately the time when loom is stopped and when loom is running.

23 *Loom fixing.* Operations in adjusting a loom by the loom fixer while the loom is stopped.

(*a*) Record only work done by loom fixer.

24 *Take up spare ends (rayon warps principally).* Operations in shortening spare warp ends.

25 *Bang-off.* False stop of a loom, requiring no work by the weaver except to pull the shipper handle and restart the loom.

(*a*) The principal causes of bang-off are loose warp or filling threads and improper adjustment of the loom.

Robert Dudley Smith

REFLECTIONS

An Engineer's Philosophy Based on Fifty Years of Experience With Human Nature

By O. P. HOOD

FIFTY years ago a class of three graduates headed a procession of alumni that Rose has since prepared for life and industry. All three of these men return today to welcome the fifty-first group as they join the 1570 graduates who preceded them. It is not often that after half a century a reunion can be held of 100 per cent of a college class so that this occasion has in it an unusual element.

How it comes that this small group remains intact it is useless to speculate, but it is evident that in addition to a measure of good luck the class was composed of persistent ones of fairly tough fiber, else they would not be here.

Each of the group has found a place in the world of work, has carried on, and has completed the conventional period of a normal lifetime. Each is therefore able to look backward along a trail of half a century of effort and experience while the present graduating class is looking forward at the other end of a career. This situation suggests a topic for the alumni address. What more natural than to report to these new pilgrims some of the things that one of the travelers has observed along this long road, hoping that some word or direction may prove helpful. The details of the road are never twice alike nor do two observers see the same things; nevertheless certain general features are evident and these can be brought to the attention of later travelers.

My first observation is that the road has not been long. It is with utter amazement that I find myself at the far end of it. It does not seem possible that I could have counted right. It seems but a short time ago that we listened to Colonel Thompson, "the silver-tongued orator of the Wabash," address a first audience of a Rose commencement in 1885 in the assembly room at the top of the old building on 13th Street. The road with all its ups and downs, its exhilarations and disappointments, does not look so somber from this end as it did from the other.

The year 1885 was part of a depression period. Jobs were scarce. Industrialists had not acquired the habit of looking over young graduates for likely material. Rather one had to live down the fact that he had spent some years in a college and had to prove by hard work that he had not been entirely spoiled thereby.

It seems that by doing each day what was to be done and without too much thought of the morrow the years have slipped by with accelerating speed and left no memory of dreariness or delay. I accept this as one of the blessings of the engineer's outlook on life. He is so busy creating that time does not hang heavy on his hands.

At twenty-one I was sure that by forty my race would have been run. Weeks seemed long and a year seemed a major portion of a lifetime. I wanted things to happen quickly and be done. There was the impatience of youth. But now, looking back, I observe that it is the asparagus and the spinach that grow quickly and that oaks and ideas grow slowly.

C. F. Kettering has said that it takes four years to get an idea across a table to a board of directors. Now that we know that it has taken many thousands of years for man to reach this present position, what we are to expect of one year seems less important. This better appreciation of time along the road has taught me patience and also the necessity of keeping everlastingly at it in order to get anything done. If dropped, things will not carry on by themselves.

Perfectly good ideas grow slowly and have to be cultivated and attended. In fact, if they grow too rapidly I suspect them of being weeds. Expect it to take time for your brilliant invention to revolutionize things, time for your boss to appreciate your value, and time to learn many of the lessons of life. Things do come to pass, but give them time. Don't begrudge persistence nor neglect to cultivate a reasonable patience, for you will have need for both.

I am told that there are many who have found the details of the road dull and a surprising number who doubt whether life is really worth while and who, if given a choice, would prefer painless annihilation to the struggle of living. I am glad that I have not found it so. I have found the adventure of life interesting even with its pain and I am glad I passed this way.

I credit this somewhat to the bent acquired at Rose. The physical sciences are so dependable that a study of them gives a sense of security and reality lacking in many other studies. The sun comes up regularly as it did when I was a boy.

Two times two still equals four, and we are not expecting a "new deal" in multiplication tables even if most of our present experience is in subtraction and division. The growing and evoluting conceptions of matter and of energy and of the service they can be compelled to give to man has captured and held my interest through the years. I am sorry for those people who see only "gadgets" in our creations.

These things have come to stay with us awhile and in turn to be outgrown by further progress. I am glad that I could find interest and adventure in such things and see a bit of their inward beauty, for they are very real and dependable friends.

Back of all these simple stabilities in the material world I get glimpses of a plan, something tremendously stable and reliable, the understanding of which would be very well worth while. It is these things of the physical universe that we engineers have tried to understand and to work with in harmony even as does the Creator. Besides being tremendously intriguing to a curious mind they are soul-satisfying in their verity and dependability.

Perhaps this is why I have found few engineers who think the world dull and life not worth living.

But all along the way I have found two worlds, one filled with material things that interested me most; and another world filled with strange beings like myself, and I the strangest of the lot, composed of material and obviously a part of the world of things, but also possessed of a something that made them utterly different. I have never been so fully at ease with them, least of all with myself. because of their strange ways,

An address read at the fiftieth anniversary commencement of Rose Polytechnic Institute, June, 1935. Illness prevented Dr. Hood from delivering the address in person.

so lawless, so complex, so relatively unpredictable. I have moved about among them and wondered if I would ever understand. I have peered curiously at them and made shy advances and found them all interesting, most of them likable, and many of them lovable.

When perplexed because they were beyond my understanding, I have retreated to my world of things where I could better understand. I have noted this tendency in a good many engineers. From this end of the road I now think that I made a great mistake in failing to make a more persistent study of them earlier in life and to make them more a part of my universe. At the time the task seemed so hopeless, but now they and their problems have moved into the center of interest.

I find that here in this world of people one finds just what he looks for. If you are interested in kindness, gentleness, unselfishness, steadfastness, loyalty, even grandeur of character, you will find them, and in the most unexpected places if you but look. If you want a world of opposite characteristics, of boorish selfishness and egotism, of greed and unreliability, you will find them without half trying if you but look their way. So why look for them? I have found it better to overlook and to concentrate attention on what I want to find and cherish, for I have found there is so much of it all about.

Without shutting my eyes to the existence of evil, jealousy, ingratitude, and disloyalty I have found so much of the better qualities of humanity whenever I looked for them that I shall carry away a pretty good opinion of people in general as I have known them. This, again, is perhaps due to a circumstance connected with my contact with Rose.

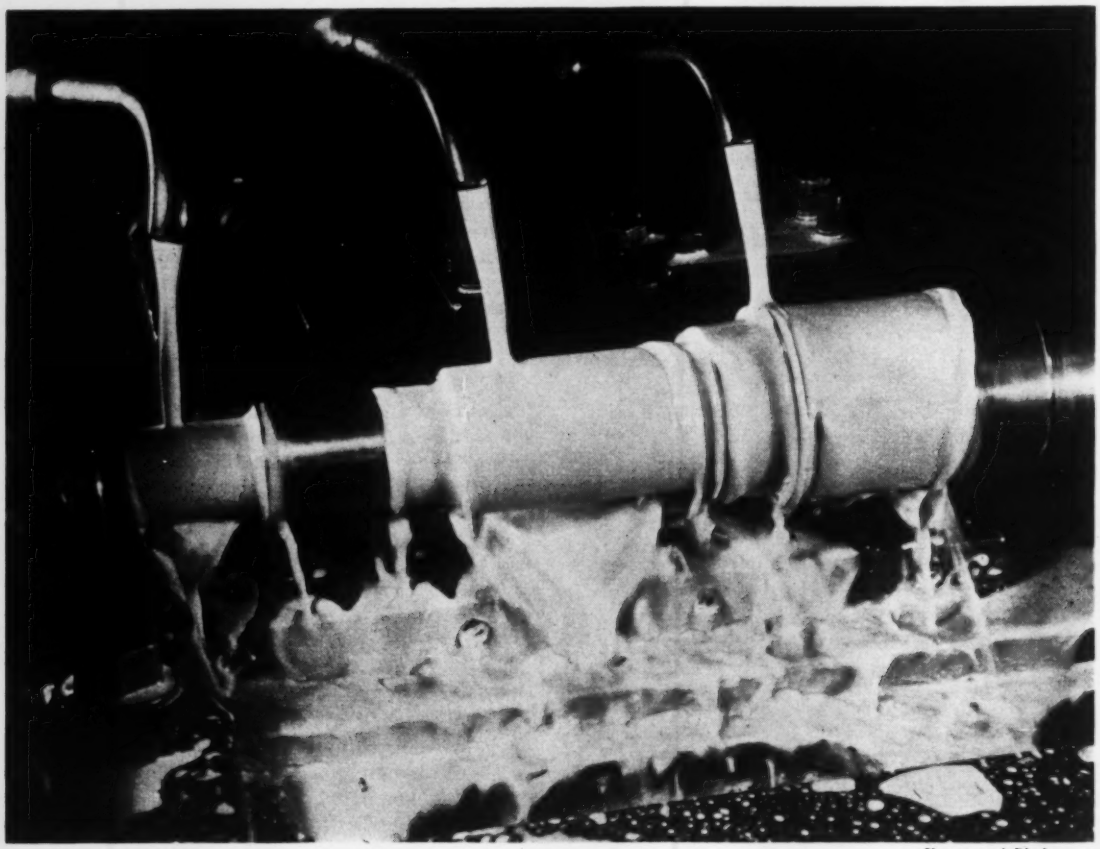
Professor Wickersham thought he saw the makings of a teacher in me and recommended me for such a job, so that I spent half a lifetime extracting an education from my contact with young college people where what is fine in human nature is abundant and easily found. But later experience with human nature, even in a Government job during the last half of the journey, has not changed my general impression. I have found the finest of human traits, together with all the rest, it is true.

These older individuals become more and more amusing in their attempts to camouflage the selfishness and little meannesses that human nature is heir to. The wounds of misplaced friendships have always been healed by balm administered by kindly and unselfish natures that could always be found, and strange enough, often under the same hat.

I have observed that opportunity and necessity seem to determine more careers than does a planned economy of life, and yet I suspect that pretty much the same sort of flowers are produced in whatever soil the bulb is planted. The essential elements of character find expression in much the same way whether the man is the executive he planned to be or the subordinate he had to be.

The net result of these contradictory observations in my world of people is to recognize the need for much charity in dealing with human nature and to hope that I, myself, may be given a generous share. This does not mean that there is no limit to patience. Patience ceases to be a virtue with some men.

But it does mean that an entirely workable philosophy of life can be acquired that will leave you at the end of the journey with a song of gladness in your heart, rather than bitterness and disappointment.



Young and Phelps

EFFECT *of* INSULATION

On the Surface Temperatures of the Contents of Galvanized Corrugated-Iron Sheathed Buildings

By D. G. WILLIAMS

TROJAN POWDER COMPANY, ALLENTOWN, PA.

THE purpose of this investigation was to determine the practical effect on the surface temperatures of the contents of an unheated galvanized-corrugated-iron-covered building in use in summer when the building is lined with an insulating sheathing, such as masonite, celotex, or similar material, as compared with the corresponding temperatures in an unlined, similarly constructed building.

The buildings were wood-frame rectangular storehouses set on concrete piers and covered on the sides and roof with 26-gage galvanized corrugated iron. The two buildings used were identical in dimensions, construction, and setting. They were 40 ft wide, 80 ft long, and 10 ft high to the eaves inside. The double-pitched roofs had a 1:2 pitch and the ridge was 10 ft above the eaves. There was no lining or sheathing under the iron on the sides or roof. The floors were constructed of 2 × 6 in. boards on 12 in. joists and the floor levels were approximately 3 ft above the surface of the ground. The frame work for the sides of the buildings was made up of 2 × 6 in. wood studs and braces.

The roof structure was made of 2 × 6 in. wood rafters and braces and 2 × 4 in. wood nailers to carry the iron. The iron roofing had begun to show external corrosion and developed leaks a year or two previous to the tests and had been "Turnerized" by applying a coat of asphaltic paint on the upper surface, followed by a layer of wet muslin with enough slack to allow for expansion, and a final coat of asphaltic paint. The resulting upper roof surface was black and somewhat rough. There was no other painting of any of the galvanized-iron surfaces. These had the normal oxidized coating.

Each storehouse had two sliding doors in front and two in the rear. These doors were open a part of the daytime during the tests but closed at night. There were also two revolving ventilators on the ridge of each building and grilles in the floor at the ends to provide incoming air when the doors were closed.

The storehouses were in the open on elevated ground and without windbreak or shade barrier. They were located in Eastern Pennsylvania in a northern latitude of approximately 40 deg 40 min.

The tests were started in June, 1931, and were discontinued from October 1, 1931, to June 1, 1932. In 1932 they were again continued from June 1 to September 10, when they were considered completed.

The temperature readings throughout were taken by means of regular stock recording thermometers with bulbs located where the temperatures were taken and recorders located where they could be readily observed. The bulbs were located so as to minimize any temperature effect due to the opening of doors. The thermometers were calibrated before and during the tests.

Contributed by the Process Industries Division and presented at a meeting of the Metropolitan Section, New York, N. Y., Oct. 7, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged.

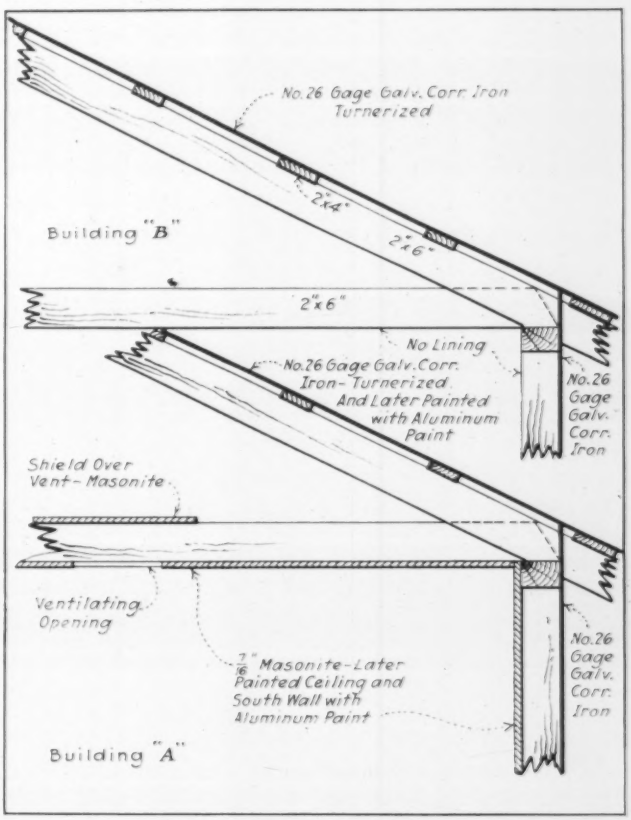

No. 26 Gage Galv. Corr. Iron Turnerized
2"x4"
2"x6"
Building "B"
2"x6"
No Lining
No. 26 Gage Galv. Corr. Iron - Turnerized And Later Painted with Aluminum Paint
No. 26 Gage Galv. Corr. Iron
Shield Over Vent - Masonite
Ventilating Opening
7/16" Masonite - Later Painted Ceiling and South Wall with Aluminum Paint
No. 26 Gage Galv. Corr. Iron
Building "A"

FIG. 1 CONDITION OF BUILDINGS WHEN TESTS STARTED

The outside atmospheric temperatures were obtained by means of a recording thermometer located in a shaded shelter at an isolated point away from the storehouses.

In preparation for the test, building *A* was lined with $^{7}/_{16}$-in. masonite placed on the inside of the 6-in. wall studs and on the underside of the crown braces forming a ceiling 10 ft high. Holes were cut through the ceiling to permit ventilation, but canopies were placed over these openings to prevent the passage of radiant heat from the roof directly into the space below. Building *B* was unlined. The details in Fig. 1 show the construction of both buildings when the test started on June 9, 1931.

On July 24, 1931, the Turnerized roof surface of building *A* was painted with one coat of aluminum bronze in spar varnish. There was apparently complete coverage and a resulting bright surface. During the period from August 6, 1931, to August 20, 1931, the underside of the masonite ceiling and the inside surface of the masonite on the south wall in building *A* were sized with "tector" and then painted with one coat of the

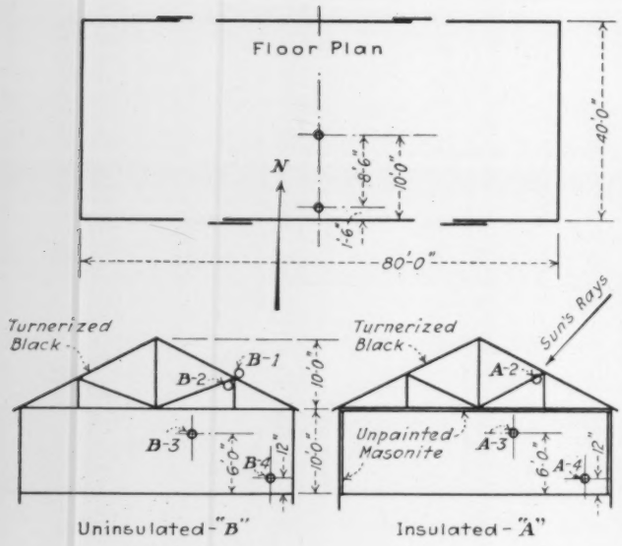


FIG. 2 TEST CONDITIONS, SHOWING LOCATIONS OF THERMOMETERS, FOR TESTS FROM JUNE 9, 1931, TO JULY 24, 1931

aluminum bronze in spar varnish. No further changes were made in the insulating factors.

SOME RESULTS OF THE TESTS

In order to study the effects on interior surface temperatures of the steps taken to improve insulation, curves were plotted for certain days showing the variation throughout 24 hours in the temperatures as recorded.

Fig. 2 shows the conditions in the buildings as they existed during the period from June 9, 1931, to July 24, 1931, and the thermometer-bulb locations in both buildings. Fig. 3 shows the plotted temperatures picked off the thermometer charts for June 30, 1931, a clear sunny day.

We assumed that the outside roof surfaces of buildings *A* and *B* would be the same and therefore took this temperature on one roof only. Readings *A*-2 and *B*-2 are comparable and apparently the space above the ceiling in building *A* was hotter than the same area in building *B*. This may be due to the fact that the radiant heat from the roof warmed the upper side of the ceiling in *A* and convection then heated the air in this space. In *B* where there was no ceiling this effect was not present.

The principal effects in which we were interested, however, were the differences between *A*-3 and *B*-3 and between *A*-4 and *B*-4 which showed the effect of the insulating lining in *A*. These temperatures are not necessarily the temperatures of the air in the buildings although they may be under certain conditions. They should be regarded as the temperatures of the exposed surfaces of the contents of the buildings where these temperatures were taken. In *B* especially, these temperatures result from heat radiated from the roof and south wall. Surfaces sheltered from such radiant heat had lower temperatures, and the air temperature in *B* was lower than the temperature of the exposed surfaces but not as low as in *A*.

It will be noted that *A*-3 and *A*-4 coincide fairly closely with the "outside" temperatures during the day indicating a minimum effect from heat radiated from the insulated ceiling and south wall. It will also be noted that roof temperatures reach their peak approximately with the zenith of the sun and then cool off at about the same rate at which they heated up. The "outside" temperature and *A*-3 and *A*-4 reach their peak about four hours later and in general together, whereas *B*-3 (and *B*-4 to a lesser extent) follow *B*-1, indicating probably that *A*-3 and *A*-4 are influenced to a maximum extent by the atmospheric temperature during the daytime whereas *B*-3 is influenced by radiant heat from inside roof and wall surfaces during the daytime. At night *B*-3 coincides with outside atmospheric temperatures more closely than *A*-3 and *A*-4, showing how quickly the inside temperature of the uninsulated building responds to outside air temperatures.

As the tests progressed, other temperature readings were plotted in the manner of Fig. 3. These showed characteristics that were affected by changes in the buildings, such as the painting of the roof of building *A* with aluminum paint in order to secure an effect similar to that of a new galvanized-iron covering, which resulted in relatively lower inside temperatures; and painting the interior insulation of building *A* with aluminum paint, which materially reduced the heat radiated from the insulated ceiling and south wall. Other plotted records showed effects of clouds and rainstorms and of an eclipse of the sun. Space will not permit the inclusion of these charts nor further comment on them.

ANALYSIS OF EFFECT OF SOLAR RADIANT ENERGY

The tests were conducted solely for the purpose of determining in practice the actual effect upon the exposed surface temperatures of the contents of insulated and uninsulated corrugated-iron buildings due to different intensities of solar heat striking such buildings, and no attempt has been made to tie up these results with theoretical considerations. There are entirely too many variables present in such actual conditions to make such a tie-up feasible. Some abstract discussion of what happens under such conditions may, however, be helpful in considering the foregoing data.

Fig. 4 is an attempt to show diagrammatically the effect of solar radiant energy upon the sheathing of a building. According to this diagram the rays of solar energy which strike the external surface of this sheathing are divided as follows:

(*a*) Rays reflected by the surface of the sheathing. The rays so disposed of have no effect upon the interior temperature of the building and the proportion reflected depends upon the reflectivity of the external surface of the sheathing.

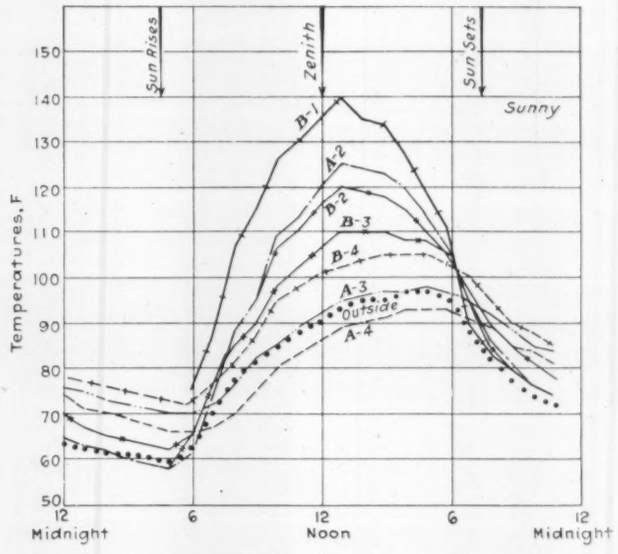


FIG. 3 OBSERVED TEMPERATURES, TEST OF JUNE 30, 1931
(Letters and numbers on curves refer to thermometers, locations of which are shown in Fig. 2.)

(*b*) Rays transmitted through the sheathing as in the case of a clear glass sheathing. There is no transmission of rays in the case of corrugated iron.

(*c*) Rays absorbed by the sheathing and transformed into heat. The rays so absorbed cause physical and chemical changes in the material absorbing them and also heat the material. The character of the external surface of the sheathing material determines the absorption of heat by this material, and the character of the material itself determines the retention, transmission, and conductivity of the heat absorbed.

It is the solar energy rays which are absorbed by the material and which raise the temperature of the material in which we are interested in this case. As the corrugated-iron sheathing continues to absorb heat it tends to reach a maximum temperature and must, therefore, dissipate most of this absorbed heat. This is accomplished as follows:

(*a*) A portion is transformed into energy and is radiated from the external surface in the form of heat rays.

(*b*) A portion is dissipated from the external surface to the external atmosphere through conductance and convection.

(*c*) A portion is dissipated to the atmosphere inside the building through the interior surface of the sheathing by means of conductance and convection.

(*d*) A portion is transformed into energy and is radiated in the form of heat rays from the internal surface of the sheathing.

In a properly ventilated uninsulated building that heat of the sheathing which is dissipated from the internal surface through conductance and convection will probably not have much effect in raising the temperature of the air inside the building above the temperature of the outside atmosphere, especially in that portion of the building where contents are usually kept.

The heat which is radiated from the internal surface of the sheathing in the form of heat rays is that in which we are mainly interested in this case. These heat rays pass through the air without materially heating it but will heat any surface upon which they strike and by which they are absorbed, and, depending upon the distance of such absorbing surfaces from the source of heat and upon the physical character of such absorbing surfaces, these surfaces may be heated to a temperature materially higher than the air temperature inside the building and surrounding such absorbing surfaces.

The introduction of a screen between the heated corrugated-iron sheathing of the building and the absorbing surface within the building will decrease the intensity of the heat rays which reach the absorbing surface or cut them off completely. Depending upon the character of such a screen it may, in turn, become a source of new heat rays of reduced intensity which can impinge upon the absorbing surface inside the building and heat it, but the material for such a screen can be so chosen that the effect of the radiant heat from the corrugated-iron sheathing of the building upon the absorbing surface within the building may be completely eliminated.

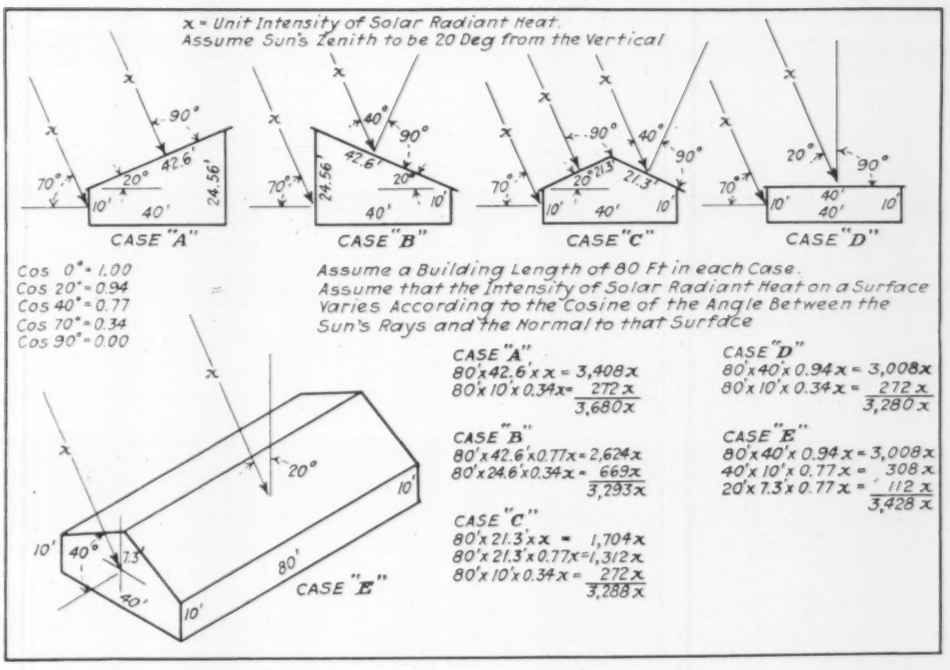

x = Unit Intensity of Solar Radiant Heat.
Assume Sun's Zenith to be 20 Deg from the Vertical
CASE "A"
CASE "B"
CASE "C"
CASE "D"
CASE "E"
Cos 0° = 1.00
Cos 20° = 0.94
Cos 40° = 0.77
Cos 70° = 0.34
Cos 90° = 0.00
Assume a Building Length of 80 Ft in each Case.
Assume that the Intensity of Solar Radiant Heat on a Surface Varies According to the Cosine of the Angle Between the Sun's Rays and the Normal to that Surface
CASE "A"
80'x42.6'x x = 3,408x
80'x 10'x 0.34x = 272x
3,680x
CASE "B"
80'x42.6'x0.77x = 2,624x
80'x24.6'x0.34x = 669x
3,293x
CASE "C"
80'x 21.3'x x = 1,704x
80'x 21.3'x 0.77x = 1,312x
80'x 10'x 0.34x = 272x
3,288x
CASE "D"
80'x40'x 0.94x = 3,008x
80'x 10'x 0.34x = 272x
3,280x
CASE "E"
80'x40'x 0.94x = 3,008x
40'x 10'x 0.77x = 308x
20'x 7.3'x 0.77x = 112x
3,428x

FIG. 5 EFFECT OF ROOF DESIGN AND ORIENTATION ON SOLAR HEAT ABSORBED BY A STRUCTURE

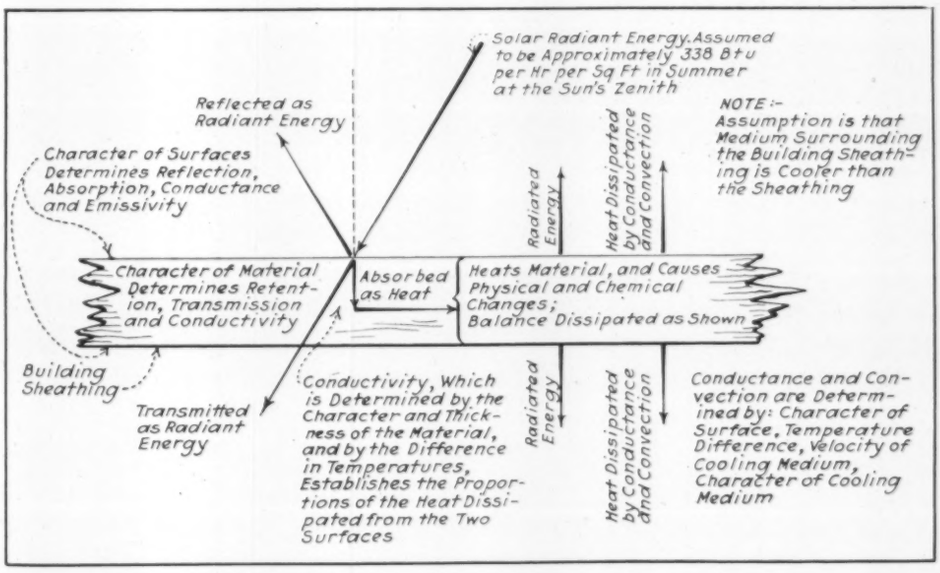

Solar Radiant Energy Assumed to be Approximately 338 B t u per Hr per Sq Ft in Summer at the Sun's Zenith
Reflected as Radiant Energy
Character of Surfaces Determines Reflection, Absorption, Conductance and Emissivity
Radiated Energy
Heat Dissipated by Conductance and Convection
NOTE:- Assumption is that Medium Surrounding the Building Sheathing is Cooler than the Sheathing
Character of Material Determines Retention, Transmission and Conductivity
Absorbed as Heat
Heats Material, and Causes Physical and Chemical Changes; Balance Dissipated as Shown
Building Sheathing
Transmitted as Radiant Energy
Conductivity, Which is Determined by the Character and Thickness of the Material, and by the Difference in Temperatures, Establishes the Proportions of the Heat Dissipated from the Two Surfaces
Radiated Energy
Heat Dissipated by Conductance and Convection
Conductance and Convection are Determined by: Character of Surface, Temperature Difference, Velocity of Cooling Medium, Character of Cooling Medium

FIG. 4 DIAGRAM SHOWING EFFECT OF SOLAR ENERGY ON BUILDING SHEATHING

ANALYSIS OF EFFECT OF FORM AND ORIENTATION OF BUILDING

An attempt was made to determine whether the form or orientation of the roof structure of a building would affect the surface temperatures within the building, and Fig. 5 shows how this determination was attempted. All buildings shown are supposed to be constructed of the same materials and in the same manner. In all cases except case *E* it is assumed that the building is so oriented that the long sides face north and south, i.e., so that the roofs pitch to the north or south, except, of course, in the case of the flat roof. According to Fig. 5, a flat-roofed building would absorb the least solar energy, but it would have the disadvantage of usually placing the heated roof surface closer to the absorbing surfaces within the building and thus offset the first-mentioned advantage. The double-pitched roof now in use appears to represent the most satisfactory form of roof structure when considered from the standpoint of the absorption of solar heat energy and the absorption of heat from the building sheathing by the contents of the building.

Case *E*, Fig. 5, indicates that changing the orientation of the building 90 deg increases the amount of solar energy absorbed by the sheathing of the building.

CONCLUSIONS

From the tests and investigations made the following conclusions may be drawn:

(*a*) Roof and wall sheathings of buildings may absorb solar heat rays sufficient to heat the sheathing to temperatures higher than outside air temperatures. Such heating depends upon the intensity of the solar heat rays and upon the character of the external surface and the material of the sheathing. In the case of a corrugated-iron roof with a black upper surface, temperatures as high as 140 F were noted on the roof sheathing.

(*b*) Exposed surfaces of contents of an unheated building may have temperatures higher than the temperature of the atmosphere within or without the building due to the effect of heat radiated from the heated sheathing of the building.

(*c*) These surface temperatures of the contents exposed to heat radiated from heated building sheathing can be, and usually are, higher than the temperatures of the contents of the building not exposed to such radiant heat.

(*d*) The nearer an exposed surface of the contents is to a heated roof or wall surface the higher the temperature of such an exposed surface.

(*e*) Exposed-surface temperatures of contents can be reduced by using building sheathing materials with higher reflective surfaces, both inside and outside.

(*f*) The greatest reduction in the exposed-surface temperatures of contents can apparently be obtained by installing insulating linings on the building sheathing.

(*g*) Temperatures of exposed surfaces of contents of uninsulated corrugated-iron sheathed buildings can be lowered at least 20 F by lining with $^{7}/_{16}$-in. masonite, celotex, or similar insulating material.

(*h*) Painting the upper, more or less rough, black roof surface with aluminum paint reduced the temperature of exposed contents surfaces by approximately 5 F. A bright galvanized surface should have the same effect as a surface painted with aluminum.

(*i*) Exposed-surface temperatures of contents in uninsulated galvanized-iron buildings may be 20 F or more in excess of the temperature of the outside air, whereas the temperatures of such exposed surfaces may be lower than outside air temperatures in insulated buildings.

(*j*) The double-pitched or ridge-roof type of building construction appears to allow for the least total amount of solar heat absorption by the external sheathing of a building of the form considered.

(*k*) The orientation of a building so that the long sides face north and south appears to allow for less total solar heat absorption by the building sheathing than does the facing north and south of the ends of such a building.

N. W. Fortey

ATMOSPHERIC AIR

The Source of Oxygen for Industry

By Wm. L. DeBAUFRE

UNIVERSITY OF NEBRASKA

OUR LIVES depend upon the composition of the atmosphere, for we live at the bottom of a sea of air. But while this has been true as long as man has inhabited the earth, it is only within the lifetime of many of us that the composition of atmospheric air has been accurately known; and the approximate nature of the atmosphere has been understood only about as long as the United States has been in existence.

Diogenes thought that air was the origin of all things. Aristotle and the alchemists of the middle ages considered air to be one of four material elements—water, air, earth, and fire. Consequently, the term "air" came to be applied to all gases as they were discovered. Differences in the characteristics of these gases were thought to be the result of different qualities assumed by the same fundamental substance "air." The word "gas" was first used by van Helmont in the 16th century and was undoubtedly derived from *Geist*, the common German word for spirit, thus indicating van Helmont's idea that a gas was a substance intermediate between matter and spirit.

EIGHTEENTH-CENTURY STUDIES OF THE ATMOSPHERE

The spirit of fire was named "phlogiston" in 1720 by the German professor of medicine Stahl, who thought the possession of phlogiston conferred capability of combustion upon certain materials. During combustion, phlogiston escaped, leaving behind an acid in the case of sulphur and phosphorus, or an earthy powder in the case of lead and tin.

"Fixed air" was the name given by Joseph Black, professor of chemistry in the University of Glasgow, to carbon dioxide distilled from limestone, as described in his thesis published in 1755. His experiments showed that fixed air was quite distinct from common air, though generally mixed with it in small quantities. He also knew that fixed air was a product of the combustion of charcoal, that it was produced during certain kinds of fermentation, and that it was exhaled from the lungs.

"Phlogisticated air" was the name given by Rutherford, a pupil of Black, to the air remaining after a candle or charcoal had burned in ordinary air until extinguished and the resulting fixed air had been absorbed in lime water. Phlogisticated air was supposed to be ordinary air saturated with phlogiston and therefore incapable of supporting combustion by absorbing additional phlogiston.

DISCOVERY OF OXYGEN BY PRIESTLEY

When Priestley discovered oxygen in 1774 by heating red oxide of mercury, he called the gas driven therefrom "dephlogisticated air," under the assumption that it contained less phlogiston than ordinary air because it supported combustion better than ordinary air. A candle burned more brightly and a piece of red-hot wood sparkled in this dephlogisticated air because of its greater avidity for phlogiston.

In 1778, Lavoisier, the eminent French chemist, gave the name "oxygen" to Priestley's dephlogisticated air. The word comes from two Greek words meaning "acid producing," and this name was selected because Lavoisier thought that oxygen was a necessary element in all acids. We have since learned that such is not the case, but have nevertheless retained the name oxygen for this chemical element.

Lavoisier called the residual portion of atmospheric air remaining after removing oxygen "azote," because it could not sustain life; and this name is still retained in French for what we call nitrogen. The word "nitrogen" comes from two Greek words meaning "niter (salt peter) producing." Nitrogen was so named because, in the words of the eccentric English scientist Cavendish, published in 1784: "Phlogisticated air appears to be nothing else than the nitrous acid united to phlogiston; for when niter is deflagrated with charcoal, the acid is almost entirely converted into this kind of air." Cavendish in 1781 analyzed samples of atmospheric air from different localities and reported it to consist of 79.16 per cent of phlogisticated air (nitrogen) and 20.84 per cent of dephlogisticated air (oxygen).

To Cavendish is also due the discovery that water is a chemical compound of two gases, one of which he called "inflammable air," the other being the dephlogisticated air of Priestley. Cavendish's inflammable air has since been named "hydrogen" from two Greek words meaning "water producing." Inflammable air was supposed to owe its inflammable quality to phlogiston contained therein.

Lavoisier, however, accounted for the phenomena of combustion without recourse to the phlogistic hypothesis. He concluded that atmospheric air simply consists of a mixture or compound of two gases, one capable of absorption by burning bodies, the other incapable of supporting combustion. Cavendish's discovery regarding water helped to confirm this theory. The fixed air of Black was concluded by Lavoisier to be a compound of carbon.

With the advent of Lavoisier's theory of combustion and its general acceptance by 1787, air was no longer regarded as a mysterious element with varying qualities due to ghostly properties. The word "air" became limited to atmospheric air, which was held to be composed of oxygen and nitrogen with small quantities of water vapor and carbon dioxide, traces of ammonia and nitrous and nitric acids, and more or less dust and micro-organisms.

The presence of water vapor in atmospheric air had been known in a general way from earliest times, as indicated by describing the element air as warm and moist in comparison with fire which was warm and dry, with earth which was cold and dry, and with water which was cold and wet. Black had shown atmospheric air to contain a small amount of fixed air, or carbon dioxide. That atmospheric air also contains a trace of ammonia was first observed by the Swedish apothecary Scheele.

Following the observations of Cavendish in 1781, more nearly exact determinations were made of the ratio of oxygen to nitrogen in dry atmospheric air. The almost constant ratio found of 21 to 79 made it appear that air might be a chemical com-

pound rather than a mechanical mixture of oxygen and nitrogen. But since this ratio is not a simple number and since there was an absence of appreciable heating or cooling upon mixing oxygen and nitrogen, air was concluded to be a mechanical mixture. Bunsen in 1846 found the percentage of oxygen to vary from 20.84 to 20.97 in one locality, and similar results were later obtained by Regnault and others by analyses of air from various parts of the earth's surface.

EARLY ATTEMPTS TO ISOLATE ATMOSPHERIC GASES

For more than one hundred years it was supposed that all the constituents of atmospheric air had been discovered. During these one hundred years, many different gases were isolated and their properties investigated by scientists in various countries. In particular, we owe much knowledge of gases to investigations made at the Royal Institution in London, founded in 1799 largely through the efforts of the American tory, Count Rumford. Humphrey Davy was engaged as its first director after having served as superintendent of the Pneumatic Institution near Bristol, a sort of hospital for treatment of disease by application of gases. Davy had experimented upon himself by inhaling various gases with almost fatal effect. Davy employed as his assistant Michael Faraday, whom we think of more often for his experiments in electricity and magnetism, but who also made many experiments on gases, particularly their liquefaction, first in 1823 and again in 1845. He combined mechanical compression with cooling, utilizing pressures as high as fifty atmospheres and temperatures as low as one hundred degrees below zero centigrade. He failed, however, to liquefy atmospheric air or its constituents, oxygen and nitrogen. The Austrian scientist Natterer was also unable to liquefy these gases even under pressures of nearly 4000 atmospheres in an apparatus built in 1845. These gases had become known as "permanent gases."

Thomas Andrews, however, in his experiments on carbon dioxide around 1870, showed that there is a critical temperature for each gas above which it cannot be liquefied by any amount of pressure. By reducing the temperature of oxygen gas to 140 degrees below zero centigrade with a cascade system of refrigeration, Pictet, in the laboratory of physics at the University of Geneva, succeeded in liquefying oxygen under a pressure of 320 atmospheres on Dec. 22, 1877, at 8 p.m. Cailletet, the French manufacturer-scientist, had obtained a mist of liquefied oxygen on Dec. 2, 1877, by sudden expansion of oxygen gas from a high pressure, thereby reducing the temperature of the gas below the critical temperature of oxygen. He likewise obtained mists of liquefied nitrogen and liquefied air.

EXPERIMENTS IN LIQUEFACTION

A combination of the methods of Pictet and Cailletet were later used by Wroblewski and Olszewski in Cracow and by Dewar at the Royal Institution in London to investigate the liquefaction of the so-called permanent gases. The critical temperature of oxygen was found to be about 118 degrees below zero on the centigrade scale so that it is necessary to cool oxygen gas at least to this temperature before it can be liquefied. The critical temperature of nitrogen was found to be about minus 146 centigrade. The critical temperature of atmospheric air was found at the intermediate value of minus 140 centigrade. Great difficulty was experienced in liquefying hydrogen, which had to be reduced to a temperature below minus 241 centigrade.

In 1894 Lord Rayleigh published the results of careful experiments at the Royal Institution on the densities of oxygen and nitrogen and atmospheric air. He prepared the oxygen and nitrogen from different sources. The density determinations for the several samples of oxygen were the same within the experimental error. Nitrogen prepared from ammonia, however, was found to be lighter than nitrogen from atmospheric air by about one part in 250. Lord Rayleigh was inclined to attribute the difference to some dissociation of the two atoms which form each molecule of nitrogen in the gas prepared from ammonia. But it was recognized that the same result would have been found if there had been some association of more than two atoms per molecule in atmospheric nitrogen.

FINDING THE RARE ATMOSPHERIC GASES

With a view to explaining the discrepancy found by Lord Rayleigh, Professor Ramsay undertook investigations upon atmospheric nitrogen at University College, London. He utilized red-hot magnesium for absorbing atmospheric nitrogen until a small residue remained. This residue was found to have a density 19 times that of hydrogen as compared with ordinary nitrogen which is 14 times heavier than hydrogen. Lord Rayleigh also reduced atmospheric nitrogen to a small residue by sparking with oxygen in presence of caustic soda, thereby producing nitrous oxide, and then removing it from the gas, as Cavendish had done many years previously. Lord Rayleigh and Ramsay joined in announcing in 1895 the discovery of a new gaseous constituent of atmospheric air. They named the new element "argon," meaning "absence of work," because they could not make it combine with any other element. Experiments were made to isolate the new element and determine its properties. Many still thought the new gas was nitrogen with three atoms per molecule. But the ratio of the specific heats under constant pressure and constant volume, as determined by measuring the velocity of sound through the new gas, indicated it to be composed of single atoms per molecule.

In seeking for a clue to possible compounds of argon, Ramsay learned of a gas, supposed to be a form of nitrogen, distilled from certain minerals by Dr. Hildebrande, of the United States Geological Survey. Ramsay secured a sample of cleveite and obtained therefrom a gas which he identified as helium from its spectrum. This element had been named helium in 1868 from the Greek word meaning "the sun" when the English astronomer Lockyer had observed its spectral lines in the sun's photosphere during an eclipse of the sun in that year. It was not until 1895 that helium was discovered on this earth and its properties measured by Ramsay. It was found to be a very light gas with a density double that of hydrogen.

Argon and helium were apparently members of a new group in Mendeleeff's periodic table of chemical elements. By comparison with other elements in this table, Ramsay in 1897 prophesied the discovery of a new element having a gaseous density about halfway between helium and argon. It also appeared probable that the argon previously isolated had associated with it another new gas of about double the density of argon. The search for these two unknown gases had already been begun by Ramsay and his assistants in 1895. Gases from various natural springs and from many minerals were examined without success.

DEVIATIONS FROM THE "PERFECT GAS" LAW

In the more than one hundred years during which more exact knowledge was being acquired by experiments upon atmospheric air and other gases, there were first discovered certain general laws which were thought to apply to all gases. Then it was found that no gas conformed exactly to these laws. For example, it was first thought that the product of the pressure and volume of a given mass of any gas was a constant at each temperature, as apparently found for atmospheric air by Robert Boyle about the middle of the 17th century. It was also

thought that the temperature of a gas remained constant as the gas was throttled from a high to a low pressure, as apparently indicated by the early experiments of Joule upon atmospheric air. When it was eventually realized that no gas exactly conforms to Boyle's law or to Joule's law, these laws were conceived as applying to an imaginary "perfect gas."

One of the imperfections of air and other gases is the change in temperature that occurs in throttling the gas from a high to a low pressure, known as the "Joule-Thomson effect" from its discoverers. This effect was utilized by Linde in Germany, by Hampson and Dewar in England, and by Tripler in the United States to cool atmospheric air below its critical temperature and thereby liquefy it without the cumbersome cascade system of refrigeration previously employed by Pictet and others. Throttling alone, however, will not produce a sufficient lowering in temperature; but by utilizing the "principle of regeneration" invented by Robert Stirling and widely applied by William Siemens about the middle of the 19th century, the cooled air may be made to cool the compressed air before throttling, thereby obtaining a cumulative effect which, with sufficiently high initial pressure, finally results in partial liquefaction.

LIQUEFACTION OF AIR

By proper equipment for cooling and throttling and a compressor for compressing atmospheric air to 100 or 200 atmospheres, any amount of liquid air can be made. It is simply necessary to remove water vapor and carbon dioxide before cooling the compressed air, as otherwise these would solidify and clog the cooling apparatus.

Dewar at the Royal Institution had kept this procedure a secret so that his production of large quantities of liquid air remained a mystery. But Hampson's apparatus, developed on the same principle, made liquid air available to scientific investigators generally. Ramsay obtained a liter or more of liquid air from Hampson and allowed most of it to evaporate. The residue was then evaporated and examined with a spectroscope. A new gas of high density had evidently been found and it was named "krypton," meaning "the hidden one." This was in June, 1898.

Ramsay then decided to investigate the possibility of the residue of nitrogen from atmospheric air including, in addition to argon, gases of lower and higher density. This was accomplished through the cooling effect of liquid air, which was used to condense a quantity of argon previously separated from atmospheric nitrogen. Upon reevaporating the liquified argon, the first and last fractions of gas were separated and examined. The spectroscope was unnecessary to show a new gas in the lightest gas fraction, for the blaze of crimson light from the electrically excited tube told its own story. The name of the new gas had been suggested by Ramsay's son, Willie, then about thirteen. He had suggested "novum" but his father said "neon" would sound better for the "new gas."

In further work on fractionation of liquid air to isolate krypton in order to determine its properties, a fifth new gas was found in atmospheric air by Ramsay, in July, 1898. It was named "xenon," meaning "the stranger."

WHAT THE AIR CONTAINS

Thus, by the beginning of the 20th century, the composition of atmospheric air had become fully known, at least near the earth's surface where man must live and carry on industrial processes. While its humidity, or content of water vapor, varies greatly, the proportions of the dry gases have been found to be remarkably constant over the earth's surface. In the International Critical Tables the composition of the dry gases of atmospheric air is given as:

Nitrogen	78.03 per cent by volume
Oxygen	20.99 per cent by volume
Argon	0.94 per cent by volume
Carbon dioxide	0.03 per cent by volume
Hydrogen	0.01 per cent by volume
Neon	12.3 parts in one million
Helium	4 parts in one million
Krypton	0.5 part in one million
Xenon	0.06 part in one million

Argon is extracted from atmospheric air and used for filling the bulbs of incandescent electric lamps, thereby permitting the metallic filament to be operated at a higher temperature with a higher light efficiency than if operated in a vacuum. Neon is also commercially extracted from atmospheric air and used for making the illuminated signs of the glowing red hue so familiar on our streets today. The other colors in these signs are obtained by argon and helium, which give different shades of blue, and combinations of the three gases with some mercury vapor which shows green.

INDUSTRIAL USES OF LIQUID AIR

The production of liquid air in quantity around the turn of the century created much popular interest, both by reason of the effects upon various substances of cooling them to liquid-air temperature and by reason of the possibility of using liquid air for power storage and production. It was even proposed to apply intense cold to the treatment of disease. The inventors of liquid-air apparatus were in the position of being able to produce in quantity a material for which there was little or no market.

But while liquid air has since come into limited use for research work at low temperatures and for purifying certain materials, there has developed only one major use for liquid air as such, namely, for making an explosive for blasting rock, as first proposed by Linde. The explosive mixture is produced by pouring liquid air over a porous mass including charcoal. While the explosion must be set off by a detonator within 15 minutes to one-half hour after adding the liquid air, there are no duds remaining after the liquid air has completely evaporated which would be liable to explode unexpectedly with possible loss of life and injury to property, as with ordinary chemical explosives.

In Europe, there are a number of small liquid-air plants used at quarries for this purpose. In Chile, a large mining operation uses liquid-air explosives. But in the United States, liquid air has not been used as widely for this purpose as its safety and economy would appear to justify, only one or two small liquid-air plants being so employed.

Success of liquid-air explosives is due to the fact that liquid air ordinarily contains a much higher percentage of oxygen than atmospheric air. The small fraction of liquid air produced by cooling and throttling highly compressed air contains more than 30 per cent of oxygen as compared with 21 per cent in atmospheric air. When this liquid air is removed from the liquefier, it vaporizes more or less rapidly, depending upon how well the containing vessel is insulated against heat leak from the atmosphere. The vapor given off contains a higher percentage of nitrogen than the liquid air, which therefore becomes progressively richer in oxygen. By the time the liquid air is poured over the charcoal, it consists of one-half or more of oxygen.

PRODUCTION OF OXYGEN

This selective condensation and evaporation of oxygen and nitrogen was utilized by Linde, Claude, and others to produce

nearly pure oxygen or nearly pure nitrogen by means of what is called a rectifying column. Before atmospheric air is introduced into the rectifying column, it must be cooled and partially liquefied. The cooling is effected by heat exchange with the oxygen and nitrogen products of rectification, which leave the rectifying column at very low temperatures.

As the exchangers and rectifier operate at temperatures below atmospheric, refrigeration must be supplied to cool the apparatus to operating temperatures and to balance heat leak from the atmosphere. In the Linde apparatus this has been accomplished by means of the Joule-Thomson effect previously described, which requires the air to be compressed to 100 or 200 atmospheres. Claude obtained the necessary refrigeration by means of an engine through which a large portion of the air is expanded to the pressure in the rectifying column. In the Claude system it has been necessary to compress the air to only 600 lb or less. There are differences in construction of the rectifying column, but fundamentally the rectifying processes are much the same in the two systems.

Nitrogen plants have been employed for furnishing nearly pure nitrogen for filling incandescent-lamp bulbs and for making cyanamid and ammonia for fertilizer. Most air-separation plants, however, have been used for producing oxygen of 99.5 per cent purity for cutting and welding purposes. When either oxygen or nitrogen of high purity is produced, the other product of rectification is discharged from an air-separation plant with a purity too low for commercial use, so that an air-separation plant is seldom used for the production of both oxygen and nitrogen.

POSSIBILITIES OF LARGER PRODUCTION OF OXYGEN FOR INDUSTRIAL USES

More than three billion cubic feet of oxygen were produced in the United States during 1929 and sold mostly for cutting and welding purposes. The commercial exploitation of the oxygen processes of Linde and Claude and the development of means for cutting and welding steel in connection therewith was a feat of considerable magnitude. No disparagement of this accomplishment is intended in saying that this production of oxygen in 1929 is insignificant compared with the amount of oxygen that could be used in various industrial processes if the price were sufficiently reduced. One reason for the present high price is the method of distribution in cylinders with the oxygen compressed to about 2000 lb. Each cylinder weighs about 135 lb and holds 220 cu ft of free oxygen which weighs only about 17 lb. The cost of distribution is therefore heavily weighted with the cost of transporting these cylinders back and forth from producer to user. For metallurgical and other industrial purposes other than cutting and welding, oxygen could be supplied through pipe lines, thereby greatly reducing the cost of distribution and at the same time reducing the cost of the oxygen.

For these industrial purposes, an oxygen purity of 99.5 per cent would be unnecessary. A purity of 90 to 95 per cent would be satisfactory. At this percentage of purity an oxygen plant can extract nearly all the oxygen from atmospheric air, while to produce 99.5 per cent oxygen about one-third of the oxygen is lost with the nitrogen. As the increased recovery can be attained with less cost for processing a given amount of atmospheric air, the price of industrial oxygen is thereby further reduced.

For these industrial purposes, much larger oxygen plants would in general be required than any that have been heretofore used for cutting and welding, for which the largest plants have barely exceeded a capacity of four tons of oxygen per day. For potential industrial purposes, plants producing up to 50 tons of oxygen per day would be required, and this increase in size would result in economics of operation which would greatly reduce the cost of the oxygen produced.

It is now possible to produce oxygen in large quantities at a cost less than five dollars per ton as compared with the present price of more than two hundred dollars per ton for oxygen compressed in cylinders. Even at this low price, oxygen is too costly to use in ordinary furnaces in power plants and for industrial heating where high efficiencies are already attained with atmospheric air supplied for combustion. This will be true for many years to come while our reserves of high-grade fuels last. But in gas making and metallurgical processes, such as the enrichment of air supplied to blast furnaces and modifying the production of steel in Bessemer converters and open-hearth furnaces where some special advantages attend the reduction of nitrogen in the products of combustion, or where variation in oxygen content of the air supplied for combustion adds the possibility of a better control of operating conditions or product, oxygen can now be produced at a cost which is economically feasible.

OXYGEN FOR METALLURGICAL USES

The use of oxygen or oxygenated air in metallurgical and other industrial processes has been of recurring interest for a number of years. Thus, a paper on "The Future of Oxygen Enrichment of Air in Metallurgical Operations" was read in 1920 before the American Iron and Steel Institute, by F. G. Cottrell, then Director of the U. S. Bureau of Mines. In 1923, the U. S. Bureau of Mines published a report entitled "The Use of Oxygen or Oxygenated Air in Metallurgical and Allied Processes," by F. W. Davis. In 1924, a symposium on oxygenated air was held by The American Institute of Mining and Metallurgical Engineers. A number of technical papers have been published in Germany on this subject. A recent viewpoint regarding the addition of oxygen to atmospheric air is to consider the net result as a beneficiation of the blast to metallurgical furnaces by reducing the nitrogen therein. The beneficiation of the blast in this way, as well as the beneficiation of the fuel and ore and flux, is a live topic with metallurgical engineers today.

As soon as it is fully realized that oxygen can now be reliably produced in large quantities at low cost, large oxygen plants will undoubtedly come into use for making manufactured gas by a continuous process, for reducing the nitrogen in the air to blast furnaces making pig iron, for modifying the production of steel in Bessemer converters and open-hearth furnaces, and for treating various non-ferrous metals and ores.

CONCLUSION

While we are still at the mercy of wind and rain and of flood and drought, of which the meteorologist can but sometimes give us short notice of their coming, we are not awed by the mystery of atmospheric air. We do not think it to be the origin of all things, neither do we consider it to be one of nature's elements with spiritual characteristics. The chemist and physicist have shown us what it is made of. And the engineer is prepared to change its composition as may be economically desirable or as dictated by a benevolent government.

The separation of oxygen from atmospheric air for general industrial purposes is a straightforward engineering procedure based upon physical-chemical laws established by scientific research and engineering practice. Extensive developments in the air-separation industry wait only upon the application of oxygen and oxygenated air upon a large scale to industrial processes in order to reduce the cost and improve the quality of the products.

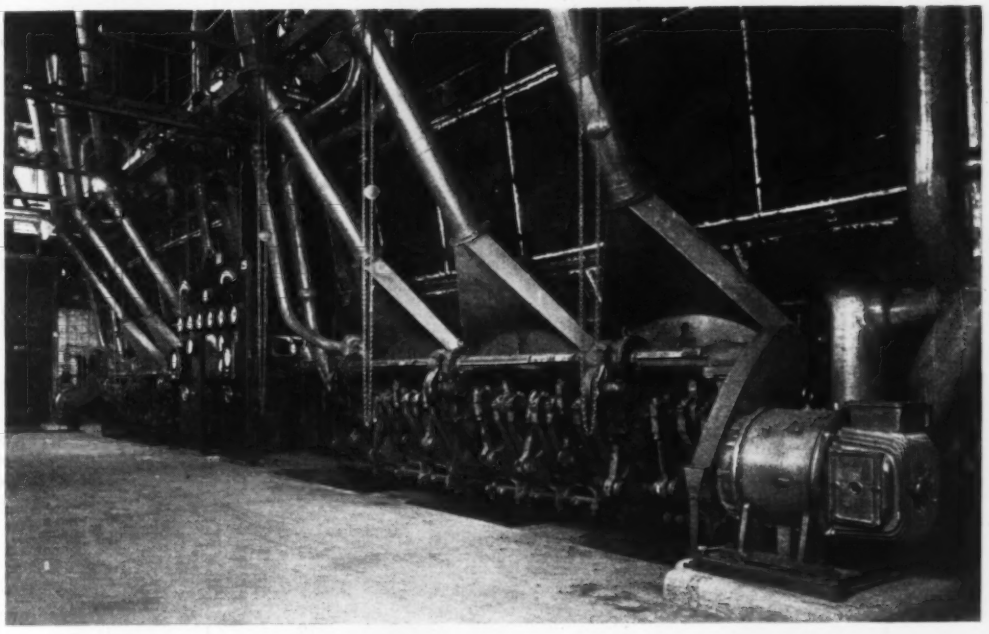


FIG. 1 TWO OF THE FOUR STOKERS OF VALLEY ROAD POWER STATION, BRADFORD CORPORATION

UNDERFEED-STOKER PRACTICE *in* GREAT BRITAIN

By W. M. DODDS

TAYLOR STOKER COMPANY, LIMITED, LONDON

THIS paper briefly reviews and illustrates some modern installations of boiler plants in Great Britain which are using the multiple-retort gravity-underfeed method of fuel burning. Figures are given where available which relate to the performance of these installations. A commentary is appended which makes brief reference to some of the more apparent differences between American and British practice.

VALLEY ROAD POWER STATION

The fronts of two of the stokers in the Valley Road Power Station of the Bradford Corporation are shown in Fig. 2. There are four stokers in the plant, each having a grate area of 292 sq ft, and the output from each boiler averages 80,000 lb per hr with periodic operation at ratings of 100,000 lb per hr. A side elevation of boiler and stoker is shown in Fig. 2.

The coals used are dry slacks, mined in the South and West Yorkshire coal fields. The sizing of these is such that more than 50 per cent will pass through a $^1/_8$-in. mesh. The other main characteristics are as follows: Fixed carbon, 49 to 57 per cent; volatile, 28 to 34 per cent; ash, 6 to 25 per cent; moisture, 2.5 to 8 per cent, and gross calorific value as fired, 10,350 to 12,300 Btu per lb.

As a constant supply of one fuel is not obtained at the power station, it frequently happens that fuels from different mines are burned simultaneously and alternately on the same stoker.

The chief interest in the installation centers around the fact that these stokers replaced older stokers of another make, with a resultant increase of about 30 per cent in capacity and of between 4 and 5 per cent in efficiency. This efficiency increase is largely due to the lowering of the leaving gas temperature by 90 F at 80,000 lb per hr evaporation. This difference in final gas temperature does not account entirely for the 5 per cent increase in efficiency, but the remainder of that increase is due to reduced carbon in the refuse; to the smaller moisture content in the fuel; to the reduction in the amount of fuel lost by sifting; and to the lower gas quantities entering the chimney. Greater understanding on these points can be obtained when it is explained that the smaller moisture content arises from the fact that it is not now necessary to add water to the fuel to facilitate combustion as was the case with the old stokers; that the heat loss consequent upon sifting is now as low as 0.08 per cent of the fuel fired; and that the CO_2 at the

Contributed by the Power Division and presented at a meeting of the Metropolitan Section, New York, N.Y., July 10, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. The original paper also contained descriptions of stoker practice at the following plants: Thomas Hedley & Co., Ltd., Manchester, England; Deptford West Power Station of the London Power Company, Ltd.; the Westkraftwerke of the B.E.W.A.G., Berlin, Germany; and a brief description of the Fulham Power Station of the Metropolitan Borough of Fulham, London, under construction.

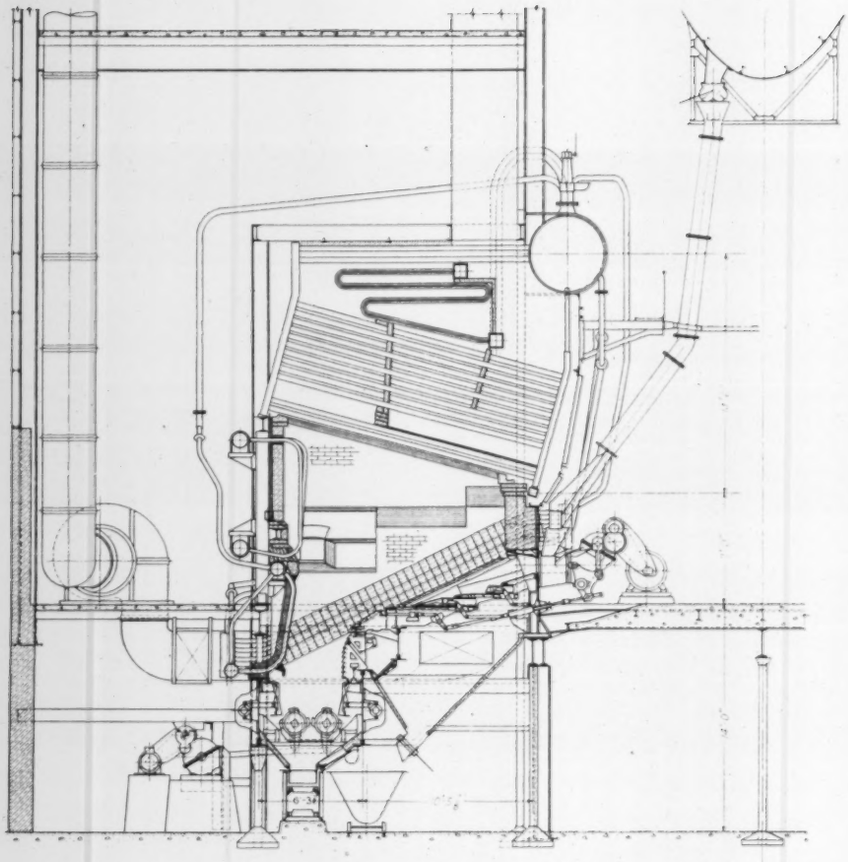


FIG. 2 SIDE ELEVATION, BOILER AND STOKER, VALLEY ROAD POWER STATION, BRADFORD CORPORATION

(Boilers: B & W type, furnace width 21 ft 1/4 in., furnace volume 3000 cu ft, heating surface 11,000 sq ft, water-wall area 212 sq ft; superheater surface 2750 sq ft (convection) 186 (radiation); economizer, Greens type, heating surface 5280 sq ft. Stoker: Taylor MC7 type, 12 retorts, 25 tuyères, 2 rolls 18 in. diam, pit depth 5 ft 7 3/8 in., grate area (projected) 292 sq ft. Ratios: grate surface to boiler surface 0.0266; cu ft furnace volume to sq ft boiler-heating surface 0.273.)

boiler outlet is now just in excess of 15 per cent as compared with an original 13 per cent.

Nevertheless, the greatest gain in efficiency undoubtedly arises from the reduced chimney temperature which, in turn, is due to increased radiant-heat transfer. The fact that there is an incidental fall of 80 F in superheat temperature proves that the radiant-heat transfer is now higher than previously, i.e., there is now less heat available for convection transfer than was the case with the original stokers.

In Fig. 3 the results on old and new stokers are compared, and the official tests which were made on the new stokers are summarized in Table 1. These tests were conducted with considerable thoroughness, and both water and fuel were properly weighed. The total power consumption for the forced- and induced-draft fans and stoker motors, as shown by the figures in Table 1, is about 20 kwhr per ton of coal burned.

BATTERSEA POWER STATION

The installation of six multiple-retort gravity-underfeed stokers in the Battersea Power Station of the London Power Company, Limited, is of considerable interest. Although, from a standpoint of evaporative capacity, these units are not as large as the units installed in the Hudson Avenue Station of the Brooklyn Edison Company, they are, to the best of the author's knowledge, the largest mechanical stokers in the world.

Battersea is the only power station in operation in Great Britain which is exclusively and completely equipped with multiple-retort stokers. It went into commission in August, 1933, and at the end of 1934 the efficiency for the first complete year of running was recorded as 27.24 per cent on a load-factor basis of 53.7 per cent. This is equal to 12,525 Btu per kw.

The projected grate area of each Battersea stoker is 752 sq ft, and the coal-burning rates correspond to a normal steaming duty of 250,000 lb per hr and to a maximum continuous steaming duty of 312,000 lb per hr. Fig. 4 shows one of these units in sectional side elevation and Fig. 5 the fronts of the six existing stokers in the station. The coals burned in the station are mostly of the Scotch and semianthracitic Welsh types, having gross calorific values of 11,000 and 13,500 Btu per lb, respectively. A series of tests has been conducted at normal output, more particularly for the purpose of testing the stokers and fuels than for the purpose of assessing the performance of the boilers. As a consequence, such efficiency figures as have been obtained are of a preliminary nature; these are given in Table 2. Two of these tests are with Scotch coal, while the third test shown was conducted with Welsh coal.

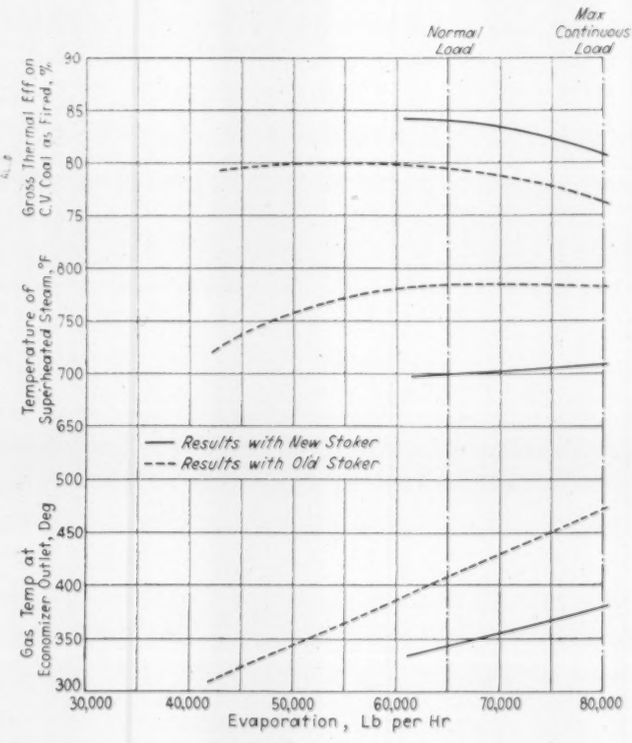


FIG. 3 COMPARATIVE RESULTS WITH NEW AND OLD STOKERS AT VALLEY ROAD POWER STATION, BRADFORD CORPORATION

Some load-variation trials have been conducted on the Battersea boilers which reflect the flexibility characteristic of the stokers. In these the rate of steam flow was altered considerably for the purpose of testing the feedwater regulators, and while an even greater degree of flexibility could have been demonstrated, if this had been the aim and object of the tests, Fig. 6 illustrates an approximate increase in steam flow equal to the full normal output of the boiler (250,000 lb per hr) in 9 min and a fall in steam flow of about 300,000 lb per hr in 12 min.

At present an extension is being made to the Battersea plant for the purpose of supplying steam to a new 110,000-kw turbo-generator, which is also being installed. The extension in question consists of three boilers which will operate normally at an output of 300,000 lb per hr and at continuous overloads of 375,000 lb per hr, with peak ratings up to 400,000 lb per hr. Steam-pressure and temperature conditions are approximately the same as those given in Table 2. The stokers for these new boilers will each have a projected grate area of 787 sq ft and will be of the multiple-retort type.

SOUTHERN RAILWAY TRAIN-FERRY STEAMERS

Southern Railway train-ferry steamers have been constructed to provide a "through" service of passenger and freight trains between London and various points on the Continent, and in particular they will make possible an overnight sleeper service between London and Paris.

Three vessels have been built, viz., the S. S. *Twickenham Ferry*, the S. S. *Hampton Ferry*, and the S. S. *Shepperton Ferry*, and the sea-going trials on all of these vessels were completed prior to the spring of this year. Practically every type of marine propulsion was considered prior to the selection of steam-turbine drives and coal-fired water-tube boilers with mechanical stokers.

The installations are unique in many respects because they introduce to marine practice a number of features which heretofore have been almost exclusively associated with steam generation on land, such as gravity flow of coal from overhead bunkers to the hoppers on the stokers; the use of slack

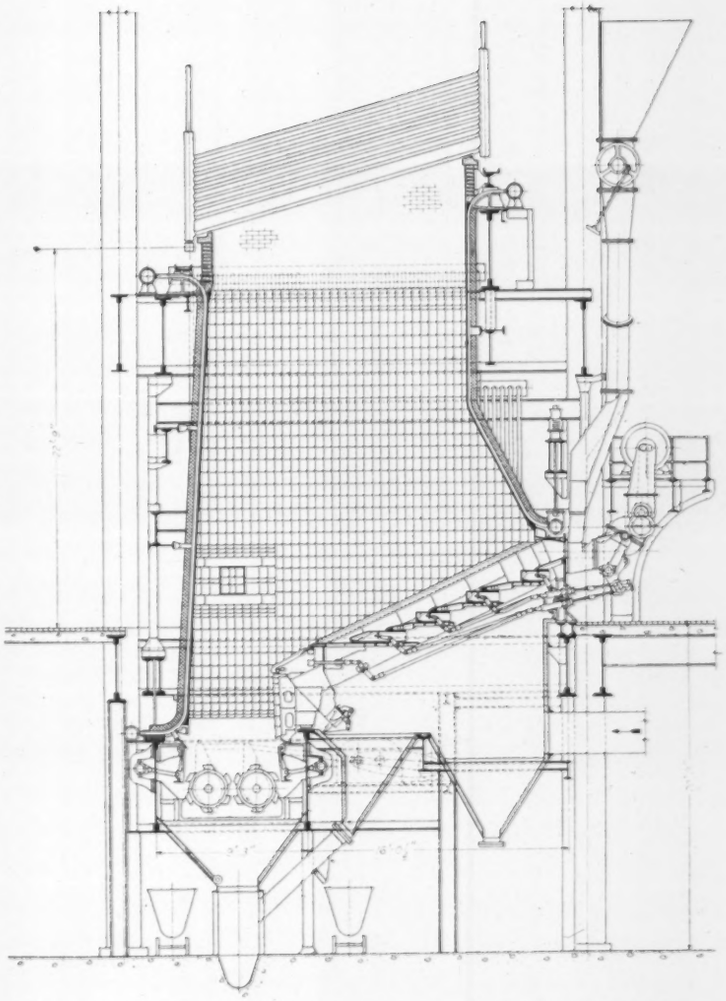


FIG. 4 SIDE ELEVATION, BOILER AND STOKER, BATTERSEA POWER STATION, LONDON POWER COMPANY, LIMITED

(Boilers: B & W type, furnace width 34 ft 11¼ in., furnace volume, 15,435 cu ft, boiler heating surface 26,580 sq ft, water-wall areas 900 sq ft (rear), 720 sq ft (side), 710 sq ft (front), 2330 sq ft (total); superheater, B & W type, heating surface 10,920 sq ft; economizer, B & W type, heating surface 17,826 sq ft; air preheater, B & W type, heating surface 57,208 sq ft. Stoker: Taylor PC7-type, 20 retorts, 49 tuyères, 2 rolls 26 in. diam, pit depth 6 ft 11½ in., grate area (projected) 752 sq ft. Ratios: grate surface to boiler surface 0.0283, cu ft furnace volume to sq ft boiler heating surface 0.58.)

TABLE 1 TESTS OF BOILER NO. 27 AT VALLEY ROAD POWER STATION, BRADFORD CORPORATION

Boiler no	27	27	*Temperatures*		
Duration of test, hr	6	6	Temp feed to economizer, F	157.90	157.50
Date of test	7/19/33	7/20/33	Total temp steam, F	698.30	709.50
Actual evaporation, lb per hr	65,000	80,000	Temp gas exit (economizer), F	341.20	379.20
Combined eff, boiler, water walls, and economizer, per cent	83.90	81.00	Temp air to stoker, F	109.40	101.80
Heat balance (as fired)			*Net efficiencies*		
Heat absorbed by boiler, water walls, and economizer, per cent	83.90	81.00	Avg draft over fire, in. water	—0.10	—0.10
			Avg air pressure in stoker wind box, in. water	2.66	3.32
			Power by stoker and crusher motors, kw	2.17	2.83
Heat loss, dry flue gases, per cent	6.61	7.18	Power by forced-draft fans, kw	41.16	59.50
Heat loss, moisture in coal, per cent	0.81	0.72	Power by induced-draft fans, kw	37.33	41.50
Heat loss, hydrogen in coal, per cent	3.70	3.80	*Analysis of Howden Clough Coal (by weight as fired)*		
Heat loss, moisture in air, per cent	0.20	0.20	Carbon, per cent	61.14	60.84
Heat loss, carbon monoxide, per cent	0.00	0.00	Hydrogen, per cent	4.01	4.04
Heat loss, carbon in refuse, per cent	1.24	1.22	Oxygen, per cent	7.29	7.52
Heat loss, radiation and unaccounted for, per cent	3.54	5.88	Sulphur, per cent	3.72	3.77
			Ash, per cent	15.93	17.11
Flue-gas data			Moisture, per cent	7.91	6.72
CO_2 in third pass, per cent	13.43	15.33	Gross heating value, Btu	11,066	11,007
CO_2 at exit (economizer), per cent	11.94	13.10	Lb coal burned per hr per sq ft grate	30.00	40.00
Steam pressure, gage, lb per sq in	210.60	211.50	Carbon in refuse, per cent	5.60	5.10
Factor of evaporation (calculated)	1.287	1.295	Btu liberated per cu ft furnace volume per hr	31,533	41,530

FIG. 5 SIX EXISTING TAYLOR STOKERS AT BATTERSEA STATION

coal of size $^1/_2$ in. to zero; and preheated air for combustion.

The construction of each ship permits of the railway coal cars being run directly onto the rail tracks on the train deck, from whence the coal is discharged directly into the bunkers in the stokehold below. Thus the entire process of bunkering and stoking is either automatic or mechanical. The only manual process involved is the removal of ash from the ashpits, which have been designed to provide an accumulative capacity sufficient to insure that ashes need only be removed once in 24 hr, thus permitting the operation to be performed while the vessels are in port and while the boilers are not under load. This is important in view of the fact that the fans deliver combustion air directly into the stokehold which is thus under pressure during service hours. From the stokehold the air flows through the preheaters to the underside of the stokers and from thence to the fires.

Each of the three vessels has four boilers of the water-tube type with superheaters and air heaters. Water is fed to the boilers at a temperature of about 270 F, and steam is generated at a pressure of 250 lb per sq in. gage with a final temperature of 505 F. The normal rate of steam output from each boiler is 16,000 lb per hr and the coals used on the trials were obtained from both Northumberland and Kent coal fields, the former having a calorific value of about 11,500 Btu per lb, while the latter had a calorific value of about 13,500 Btu per lb.

Fig. 7 is a view of the stokers under the two forward boilers on the *Shepperton Ferry* and shows the arrangement of direct gravity feed from bunkers to coal hoppers. The stokers are set very low; the distance from floor plates to center line of rams is only 2 ft 7 in.

DIFFERENCES IN TREND AND PRACTICE

During recent weeks the author has been interested in the results which are being obtained by the more modern boiler plants in the United States. Although it would be difficult to formulate any conclusive idea concerning differences or the trend in practice in the United States and Great Britain, perhaps a few general impressions can be advanced with impunity.

Apparently, there have been few new boiler plants installed by public-utility companies in this country during the last year or so that were not concieved at some earlier period, and although recent construction may be approximately representative of present opinion, the impression is that there is insufficient current design to confirm that this is so.

TABLE 2 PRELIMINARY TESTS AT BATTERSEA STATION, LONDON POWER COMPANY, LIMITED

Boiler no	1	1	1
Duration of test	24 hr 57 min	26 hr 6 min	25 hr 12 min
Date of test	9/6–7/34	10/11–12/34	11/5–6/34
Actual evaporation, lb per hr	257,794	258,695	260,613
Combined eff, boiler, water walls, superheater, economizer, per cent	89.46	88.04	89.85
Heat balance (as fired)			
Heat absorbed by boiler, water walls, superheater, economizer, per cent	89.46	88.04	89.85
Heat loss, dry flue gases, per cent	3.47	3.03	2.25
Heat loss, moisture in coal, per cent	1.21	0.97	0.45
Heat loss, hydrogen in coal, per cent	3.32	3.40	2.75
Heat loss, moisture in air, per cent	0.20	0.20	0.20
Heat loss, carbon monoxide, per cent	0.00	0.38	0.00
Heat loss, carbon in refuse, per cent	0.55	0.37	0.62
Heat loss, radiation and unaccounted for, per cent	1.79	3.61	3.88
CO_2 at exit (air heater), per cent	14.68	14.90	16.30
Steam pressure, gage, lb per sq in.	615.60	612.00	611.70
Factor of evaporation (calcd.)	1.21	1.205	1.19
Temperatures			
Temp feed to economizer, F	288.90	294.90	303.30
Total temp steam, F	833.50	836.50	825.70
Temp gas exit (air heater), F	255.30	232.50	196.90
Temp air entering preheater, F	103.70	97.90	90.50
Temp air to stoker, F	270.90	261.50	249.10
Net efficiencies			
Avg draft over fire, in. water	—0.03	—0.04	—0.03
Avg air pressure in stoker wind box, in water	0.66	1.15	1.75
Power by stoker and crusher motors, kw	4.63	4.74	3.94
Power by forced-draft fans, kw	126.50	134.00	118.00
Power by induced-draft fans, kw	427.00	247.00	209.00
Heat equivalent of 1 kwhr, Btu	14,000	14,000	14,000
Reduction on gross eff for net eff, per cent	2.48	1.73	1.39
Net eff on gross heating value (as fired), per cent	86.98	86.31	88.46
Analysis of coal (by weight as fired)			
Name of coal	Scotch washed pea	Scotch washed pea	Rhymney Valley duff
Carbon, per cent	65.36	68.87	80.34
Hydrogen, per cent	3.80	4.12	3.88
Oxygen, per cent	8.98	7.38	3.34
Nitrogen, per cent	1.10	1.28	0.83
Sulphur, per cent	0.85	0.67	0.74
Ash, per cent	7.40	7.15	5.16
Moisture, per cent	12.51	10.53	5.71
Gross heating value, Btu	11,610	12,190	14,040
Lb coal burned per hr per sq ft grate	38.60	37.35	31.61
Carbon in refuse, per cent	5.43	3.88	9.34
Btu liberated per cu ft furnace volume per hr	21,478	21,823	21,272

It would also appear that there might be a great deal of new plant and extension work in the offing, and it seems possible that a period of considerable activity may be imminent. Extension work of this type has been going on in England during the past eighteen months.

There is an idea prevalent in steam-generating circles in Great Britain that American fuels are superior to those available in the British Isles, and from superficial examination that might appear to be the case. Speaking generally, the heating value of fuels met with in this country is higher than the corresponding heating values on the other side of the Atlantic. It might be said that this difference is of the order of 200 to 250 Btu per lb, and it is this difference, presumably, which is responsible for the impression in question.

It is fairly obvious that there is less day to day variation in this country in the calorific value of any specific type of fuel delivered to central-station consumers than there is in Britain. On the other hand, problems are apparently being met with here due to the lower ash content of fuels which are not experienced to the same degree in British practice. Furthermore, it would appear that ash of low fusion temperature is more prevalent in the United States than on the other side.

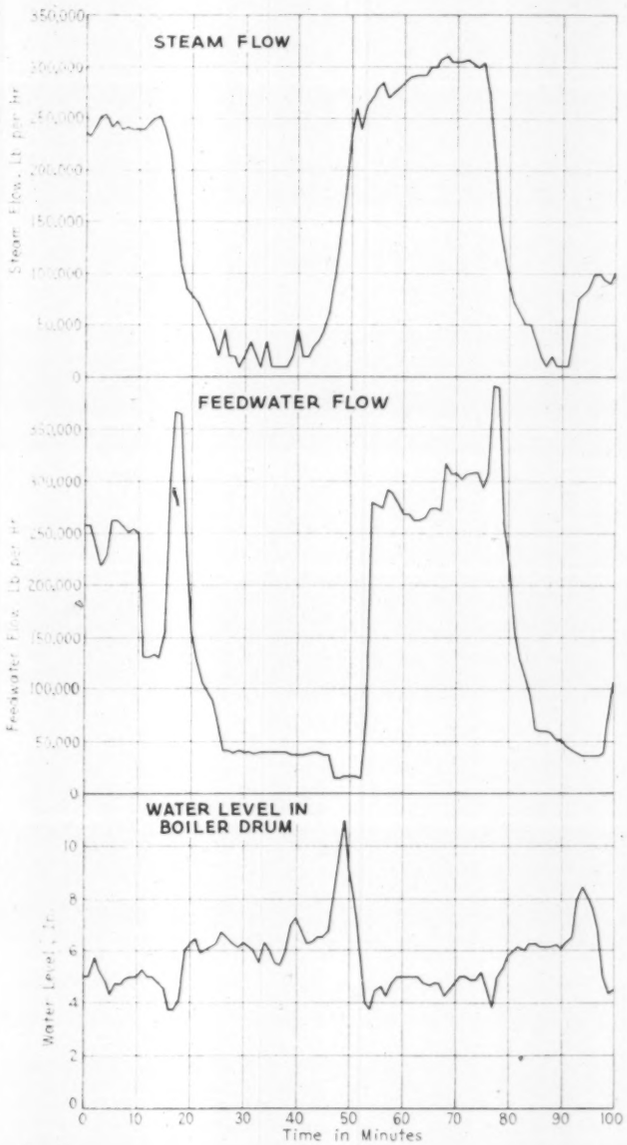

STEAM FLOW
Steam Flow, Lb per hr
FEEDWATER FLOW
Feedwater Flow, Lb per hr
WATER LEVEL IN BOILER DRUM
Water Level, In
0 10 20 30 40 50 60 70 80 90 100
Time in Minutes

FIG. 6 RESULTS OF FEEDWATER-REGULATOR TESTS AT BATTERSEA

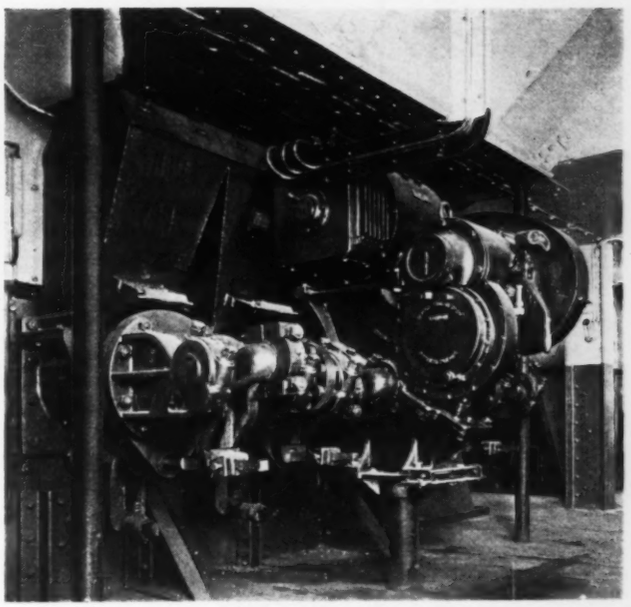


FIG. 7 UNDERFEED STOKERS "SHEPPERTON FERRY"

Passing from the general to the particular, it by no means follows that all American fuels are of the high-calorific type, nor that the problem of the American operator is less difficult than that of the British operator. A good example of this is revealed by a plant recently visited by the author wherein the problem of obtaining maintenance-free operation with 375-F air preheat on underfeed stokers burning Illinois coal of 10,900 Btu per lb and having an ash-fusion temperature of 1900 F had been effectively solved.

On the other hand, a favorable aspect of steam-raising fuels in this country, which is not usually met with in Britain, is the invariable presence of some large-size pieces in coal which is otherwise almost entirely formed of very small particles. The presence of these large pieces is conducive to obtaining an efficiency of coal flow with bunker and chute designs, which would be substantially ineffective with most British fuels which, generally speaking, in the absence of the admixture of lumps with fines, have a tendency to produce excessive packing and consequent inefficient feeding.

There is another apparent difference where coal supply is concerned which results from the difference in size in the two countries. In Britain any particular plant, especially if built where it may receive sea-borne fuel, has more equal access to mining areas which produce coals of varied quality, and it is therefore prevalent in Britain to find plants burning varied types of coal in the same boiler house at the same time. There does not appear to be much evidence of situations of this type in boiler houses owned and operated by American public utilities.

As far as operation is concerned, there are fairly well-defined differences. In general, the American plants are operated at higher ratings, and there is less desire to reduce the temperature of chimney gases to low levels. Furthermore, the peak-rating practice is in greater evidence in this country where instead of keeping additional boilers in service for emergencies the practice is being adopted of designing the plant and organizing the staff to obtain high overloads on specific boilers as and when required.

Separation of RADIATION *and* CONVECTION HEAT LOSSES

By SYDNEY STEELE

GORDON McKAY FELLOW, HARVARD UNIVERSITY

SEPARATION of the total heat lost by a body in still air into its radiation and convection components has hitherto occasionally been accomplished by determining (in addition to values of total heat loss) either the relative amounts of energy radiated by the body with two surface treatments (1, 2, 3),[1] or the absolute value of the surface emissivity within the required range of surface temperatures (4). More often it has been customary to assume a value for the surface emissivity based on the best available data (5).

A method has recently been outlined (6) which, under certain conditions, enables both radiation and convection components to be determined from a series of observations of total heat loss at not less than three separated temperatures within a range of about 1000 F. Three conditions were laid down, namely, that: (*a*) Air temperature is kept constant while body-surface temperature is varied; and that, over the temperature range employed, (*b*) the coefficient of natural convection for the body in Btu per sq ft per hr per (deg F)$^{5/4}$ remains sensibly constant; and (*c*) surface emissivity varies linearly with surface temperature.

DESCRIPTION OF METHOD

Referring to the nomenclature at the end of the paper

$$H = H_r + H_c \quad \ldots\ldots [1]$$

and from reference (7)

$$q = 0.172\ A\ F_A\ F_E[(T_s/100)^4 - (T_a/100)^4]$$

which, for a heated pipe small compared with the enclosing room (8) reduces to

$$H_r = 0.172\ p\ [(T_s/100)^4 - (T_a/100)^4] \quad \ldots\ldots [2]$$

and

$$H_c = C\ (T_s - T_a)^{5/4} \quad \ldots\ldots [3]$$

There is now little doubt concerning the accuracy of Equation [2] when applied to radiation with essentially black-body distribution; but it is not so certain that, even in the restricted temperature range employed (0 to 1000 F, approximately), C is constant, or that the correct exponent of $(T_s - T_a)$ in Equation [3] is $^5/_4$. This exponent appears, however, to be fairly generally accepted (9, 10, 11), although for surface temperatures below about 300 F there is evidence that, for the data analyzed in this paper, its value decreases and that C therefore cannot be considered constant. This is discussed later.

Fig. 1 shows Equations [2] and [3] plotted against $(T_s - T_a)$ in opposite directions from zero for several values of p (0.6 to 1.0) and C (0.25 to 0.50), for a constant air temperature of 80 F. A separate set of radiation curves must be used for each air temperature, although changing T_a does not alter the position of the convection curves. If data are to be analyzed graphically, it is advisable to change the vertical scale at possibly two values of $(T_s - T_a)$ and to plot values of H_r and H_c to as large a scale as convenient. If greater accuracy is required, H_r and H_c may be calculated for all values of $(T_s - T_a)$ for which observations of H are available.

The method of separating convection and radiation losses is conveniently described by assuming both a "correct" value for the coefficient of natural convection C and also the relationship between the surface emissivity and temperature, p and t_s, and demonstrating the effect produced on this relationship by varying C in equal steps from the correct value. The emissivity-temperature relationship for a hypothetical body is accordingly assumed to be as in Fig. 2*a*, and the experimental conditions are presumed to require that the correct value of C be 0.40.

In analyzing any given set of data the procedure is to select a convection curve, Fig. 1, as base line, and at appropriate abscissas to erect vertical distances equivalent to the total heat loss. The other end of each vertical distance becomes a tracing point, which indicates the value of surface emissivity which

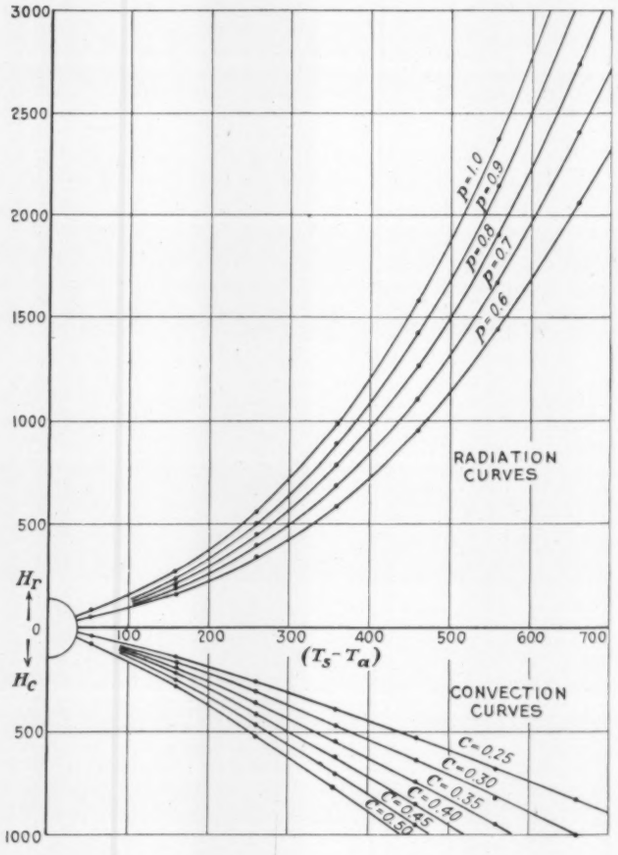


FIG. 1 CURVES OF RADIATION AND CONVECTION HEAT LOSS CALCULATED FROM EQUATIONS [2] AND [3] FOR AIR TEMPERATURE OF 80 F

[1] Numbers in parentheses refer to the bibliography at the end of the paper.

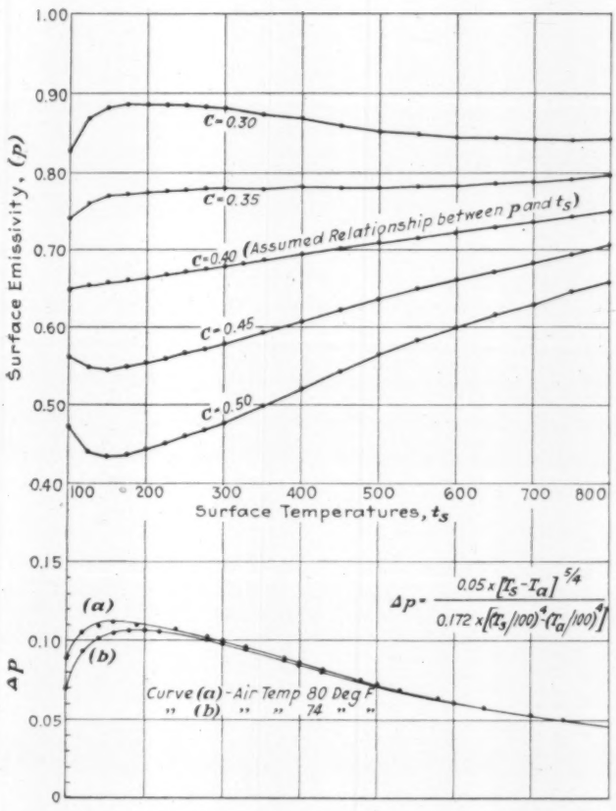


FIG. 2*a* (TOP) EMISSIVITY-TEMPERATURE RELATION *b* (BOTTOM) VALUES OF Δp FOR 80 AND 74 F AIR TEMPERATURES

would account for radiation loss if convection loss had been correctly gaged. For each selected convection curve a set of values is traced out for p, and all sets are plotted against surface temperature.

Since in Fig. 1 convection curves are drawn for values of C changing by steps of 0.05, at any abscissa the vertical distances between adjacent curves will be equal. Let this distance, measured in any convenient unit, be δ_c. Similarly, the vertical distances between adjacent radiation curves are also equal and (for the same abscissa) may be designated δ_r, measured with the same unit of length. The effect of moving from any convection curve to the adjacent one for a given value of $(T_s - T_a)$ is, therefore, to move the tracing point, i.e., the other end of the distance representing total heat loss, a distance represented by δ_c in the region of radiation curves. If the length δ_r actually represents a change of 0.10 in the value of p, as in Fig. 1, the distance δ_c will represent a change in the value of p equal to $0.1\ \delta_c/\delta_r$, conveniently designated Δp.

With values of C changing by 0.05, or any selected value, the variation in Δp with t_s is readily determined. Values of Δp are most accurately calculated from Equations [2] and [3]; this was done in preparing Fig. 2*b*, the calculated values for which appear also in Table 1.

From Fig. 2*b* the change in p produced by moving from any convection curve in Fig. 1 to the adjacent one can be read at any surface temperature, and sets of points corresponding to assumed values of 0.30, 0.35, 0.45, and 0.50 for C are marked on Fig. 2*a*. As originally outlined (6) the method at this point consisted in drawing the best-fitting straight line through each set, and then selecting as most probable the set which deviated least from its own line. As shown later, this should be done if only isolated values of H are available, but if a smooth curve giving variation in H with $(T_s - T_a)$ is available, a simpler procedure may be adopted.

APPLICATION OF METHOD

To illustrate the application of the method three sets of data were selected at random from the literature, namely, those of McMillan (12), Heilman (13), and Griffiths and Jakeman (14).

McMillan used a standard steel pipe, 5.56 in. outside diameter, containing oil electrically heated to temperatures varying from 50 to 450 F above the temperature of the surrounding air. Air temperature was apparently constant at 80 F, and results were expressed as heat loss in Btu per sq ft per hr per Δt vs. Δt.

Heilman used wrought-iron pipes, 1.315 in., 3.5 in., and 10.75 in. outside diameter, electrically heated to temperatures varying from 50 to 700 F above the temperature of the surrounding air. Air temperature was reported to have varied less than 1.8 F from a mean of 81 F, and the results were later (4) given in Btu per sq ft per hr per Δt, corrected to an air temperature of 80 F.

TABLE 1

	Δt	Δp	
t_s	(t_a = 80)	t_a = 80	t_a = 74
130	50	0.1065	0.0965
180	100	0.1110	0.1062
200	120	0.1101	0.1063
230	150	0.1079	0.1051
280	200	0.1020	0.1001
300	220	0.0990	0.0974
330	250	0.0951	0.0938
380	300	0.0879	0.0871
400	320	0.0852	0.0845
430	350	0.0812	0.0807
480	400	0.0748	0.0743
500	420	0.0723	0.0720
530	450	0.0688	0.0685
580	500	0.0634	0.0632
600	520	0.0612	0.0611
700	620	0.0521	0.0520

Griffiths and Jakeman used iron pipes, 4.5 in. and 9.0 in. outside diameter, electrically heated to temperatures up to about 650 F. Unfortunately, air temperature varied from 59 to 93.5 F. Results from these pipes and from two others, one a 4.5-in. outside diameter steam-heated iron pipe, were all plotted as Btu per sq ft per hr per Δt vs. Δt. Strictly speaking this should only be done for results obtained from one pipe size with a reasonably constant air temperature, since the convection component of heat loss depends also to a certain extent on pipe size and the radiation component on the absolute level of temperature. When analyzing these data by the present method the average air temperature, 74 F, was used.

For all the aforementioned data numerical calculations were made of the emissivity, at each selected Δt, which would account for the radiation loss if the convection coefficient C were equal to 0.30. Emissivities corresponding to other values of C were then plotted, using values of Δp obtained from the appropriate curve in Fig. 2*b*.

Fig. 3*a* shows the result for Heilman's data from the 1.315-in. pipe, Fig. 3*b* the result for the same author's data from the 3.5-in. and 10.75-in. pipes.

It will be observed that for surface temperatures less than about 300 F, a pronounced change takes place in the trend of the points. This change occurs at almost identically the same temperature for the data of all three authors, and its possible significance is reviewed later. It is clear that for these data the method of analysis ceases to be significant below about 300 F.

For the data of Heilman this leaves a significant temperature range of 300 to 700 F. Referring now to Fig. 2*a* and the same

temperature range, by placing a straightedge over the points representing emissivities at 300 and 700 F it will be seen that for values of C greater than the assumed correct value the points lie above the straightedge, while for values of C less than the correct value the points lie below. This simple criterion applied to the points in Figs. 3*a* and 3*b*, together with the fact that a decrease in emissivity with increasing temperature is improbable, indicates substantially the same p-t_s variation, and a different C, for each pipe. The indicated p-t_s variation, if assumed to hold for temperatures less than 300 F, checks almost exactly, over the range 100 to 700 F, with that determined by Heilman (4) for the material of his pipes, using radiation apparatus. The values he obtained were 0.945 at 100 F, and 0.975 at 700 F.

For the data of McMillan the same trend was observed in the points below about 300 F, so that the significant range was reduced to 200 F, from 300 to 500 F. Reference to this range in Fig. 2*a* shows that it is not sufficiently sensitive to give a definite result. This was confirmed when the data were plotted either as obtained by the author, or as subsequently modified and recommended by McAdams (15).

The data of Griffiths and Jakeman, Fig. 3*c*, display the same trend below 300 F, but the remaining range, 300 to 660 F, is large enough for the method to be significant. The probable value of C appears to lie between 0.325 and 0.250, and the corresponding values of p range from about 0.73 at 300 F to about 0.98 at 660 F. The average value 0.855 is fairly close to the value of 0.84 assumed by these observers to separate radiation and convection losses, although some doubt necessarily attaches to deductions made from data averaged from four pipes, two different pipe sizes, and air temperatures varying from 59 to 93.5 F.

THE VALUE OF "C"

Above About 300 F. Data in the literature are correlated differently, and do not agree closely. Table 2 shows, for the

TABLE 2

Observer	D'	Values of C (*a*)	(*b*)	(*c*)
Heilman	1.315	0.438	0.392	0.325
Heilman	3.500	0.390	0.307	0.275
Griffiths and Jakeman	4.500	0.381	0.288	Between 0.250 and 0.325
	9.000	0.375	0.242	
Heilman	10.750	0.375	0.232	0.225

pipe sizes utilized in this paper, the values of C recommended by (*a*) Fishenden and Saunders (16) and (*b*) McAdams (17), together with (*c*) the values indicated in the present analysis. The values in column (*a*) were obtained from a plot, on logarithmic paper, of "probable values of C based on the best experimental evidence." McAdams proposes the equation

$$h_c = 0.42\,(\Delta t/D')^{1/4} \quad \ldots\ldots [4]$$

which is equivalent to

$$H_c = 0.42/(D')^{1/4}(\Delta t)^{5/4} \quad \ldots\ldots [5]$$

so that the values in column (*b*) are listed under $C=0.42/(D')^{1/4}$.

Below 300 F. The three sets of data herein analyzed display the same tendency below 300 F, namely, that if C and the exponent of $(T_s - T_a)$ in the convection formula are assumed to remain constant in this region, surface emissivity and/or the power of T_s in the radiation formula must increase to account for the radiation loss as determined by difference. This is improbable, and changes are more likely to take place in the exponent of $(T_s - T_a)$ and/or in C. It is possible, but highly unlikely, that identically the same type of error occurred in recording observations at three different laboratories on five different pipe sizes.

McAdams' correlation of natural convection data from single horizontal pipes to air at room temperature (17) results in Equation [4],

$$h_c = 0.42\,(\Delta t/D')^{1/4} \quad \ldots\ldots [4]$$

and an inspection of the plot shows that over a wide range of values of $\Delta t/D'$ the agreement is reasonably good. (The data of McMillan and Heilman are included.)

A more comprehensive correlation (18), covering data on heat loss to air and water, shows that when the product of the

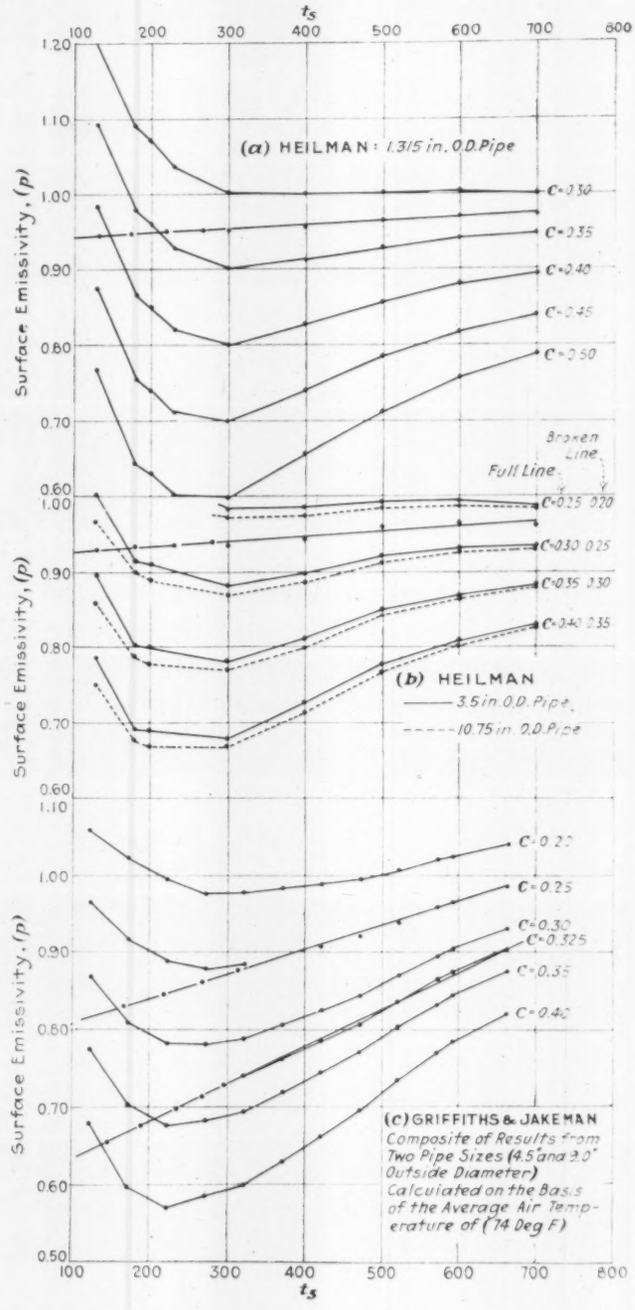


FIG. 3 VALUES OF EMISSIVITY FROM HEILMAN (FIG. 3*a* AND FIG. 3*b*) AND GRIFFITHS AND JAKEMAN (FIG. 3*c*)

Grashof (Gr) and Prandtl (Pr) numbers, which are given in the nomenclature, is greater than about 1000, the following equation holds for single horizontal pipes or wires

$$h_c D/k = 0.525\,[(D^3\rho^2\beta g\Delta t/\mu^2)(c_p\mu/k)]^{1/4} \quad \ldots\ldots [6]$$

which may be written as

$$h_c = 0.525\,(\Delta t/D)^{1/4}\,(\rho^2\beta g k^3/\mu)^{1/4}$$

and for air over a restricted temperature range the final term is sensibly constant, leading to an equation of the type

$$H_c = \text{constant}/(D)^{1/4}\,(\Delta t)^{5/4} \quad \ldots\ldots [5]$$

or

$$H_c = C\,(\Delta t)^{5/4} \quad \ldots\ldots [3]$$

for a given horizontal pipe or wire in air at atmospheric pressure. When the product (Gr × Pr) is less than 1000, the power decreases and the values of $h_c D/k$ are greater than values of this function calculated from Equation [6]. Since for all the data analyzed herein the product (Gr × Pr) is greater than 10^4 it would appear that the one-fourth power should hold, and that in consequence H_c should be proportional to $(T_s - T_a)^{5/4}$.

Heilman (4) analyzed his own convection-loss data and concluded, for the 3.5-in. pipe mentioned, that the exponent averaged 1.19 in the temperature range Δt = 100 to 350 F, and 1.23 in the range Δt = 350 to 700 F. The average for the whole range was 1.21. Similar variations in the exponent were deduced from Heilman's measurements of heat loss from a silver disk, and from the published curves of other authors. Heilman proposed the equation

$$H_c = 1.016\,(1/D')^{0.2}\,P^{0.533}\,(1/T_{avg})^{0.181}\,(\Delta t)^{1.265} \quad \ldots\ldots [7]$$

which fits his data almost exactly, over the entire experimental range. He remarks, "It is therefore readily apparent that while the variation with Δt can be forced to follow an exponential straight line having a given slope, with little error, in order to determine accurately the true heat loss it is necessary to introduce another factor into the equation which will take care of this variation. The factor $(1/T_{avg})$ serves to fill in this gap."

The fact that Heilman found the law of five-fourths power to be not strictly true either for his own data or for the data of other observers is supported by the evidence of Fig. 3, and the demonstration of the departure from the generally accepted law is due to the sensitivity of the analyses. When these data are plotted on logarithmic paper the agreement with the law of five-fourths power is made to appear much closer. Until more figures are available, however, this is probably the best assumption to make, although it would be interesting to use Heilman's empirical Equation [7] in an analysis of the type outlined in this paper.

THE PRECISION OF THE METHOD

If values of total heat loss at different temperatures are taken from a smooth curve, the accuracy of the results given by the present analysis is governed by the accuracy of the original curve.

If only isolated values of total heat loss are available, the accuracy of these values alone determines the precision of the analysis. For example, referring to Fig. 2*a*, if the probable error in determining H is equivalent to a change in the value of p which is greater than the departure of the points marked $C = 0.35$ or $C = 0.45$ from the best-fitting straight lines through them (under these conditions the procedure originally outlined (6) is utilized in the analysis), the method will not be sensitive to changes of 0.05 in C, but to some larger change. This was exemplified in the application of the method to the data of Griffiths and Jakeman.

So much depends on the extent of the temperature range available for analysis that it is not possible to give general figures, but in Table 3 values of Δp are given (at various temperatures) corresponding to an error of 1 per cent in determining H, when $p = 0.9$ and $C = 0.30$. These figures indicate the order of the accuracy required, which can be attained in practice without much difficulty.

TABLE 3

(Showing change in p (Δp) corresponding to a 1 per cent change in the value of H, when t_a = 80, C = 0.30, p = 0.90, for different values of Δt

Δt	50	100	200	300	400	500
Δp	0.0155	0.0157	0.0151	0.0143	0.0135	0.0128

Under these conditions it is apparent that the precision is increased by increasing the number of determinations of H at any given t_s, and by increasing the range of t_s. Although the sensitivity of the method increases with increasing range of t_s, the limit is set by the value of t_s beyond which the variation of p with t_s is no longer approximately linear.

GENERAL APPLICATION

It has been suggested by J. F. Downie Smith, of the Graduate School of Engineering of Harvard University, that the method here described might be generally applied, and not be confined to surfaces for which the emissivity-temperature variation can be taken as approximately linear. This would require that the method indicate both the nature and location of the $(p\text{-}t_s)$ curve, and a theoretical investigation has shown that this may be so under certain conditions. Until more data are analyzed it is not possible to put forward the general proposition with any certitude.

A general method of this type should, however, be useful in analyzing data obtained under different conditions from a variety of surfaces for which absolute values of emissivity are not accurately known, but for which the emissivity-temperature variation is approximately linear, and the general form of the expression for convection heat loss is known with some certainty. The fundamental factor in the analysis is the departure from linearity of the function Δp plotted in Fig. 2*b*.

ACKNOWLEDGMENT

The author wishes to thank Mr. Smith for constructive criticism during the preparation of this paper, and for his continued interest.

NOMENCLATURE

Symbol	Unit	Significance
C	Btu per sq ft per hr per (deg F)$^{5/4}$	Coefficient of natural convection (Fishenden and Saunders)
D	Feet	Outside pipe diameter
D'	Inches	Outside pipe diameter
Gr	Dimensionless	Grashof number $= (gD^3\beta\Delta t\rho^2/\mu^2$
H	Btu per sq ft per hr	Total heat loss from surface
H_r	Btu per sq ft per hr	Radiation component of heat loss
H_c	Btu per sq ft per hr	Convection component of heat loss
P	Atmospheres	Absolute air pressure
Pr	Dimensionless	Prandtl number = 1/Stanton group $= (c_p\mu/k)$
T_s	F absolute	Surface temperature
T_a	F absolute	Temperature of surrounding air and surfaces
T_{avg}	F absolute	Arithmetic mean of T_s and T_a
c_p	Btu per lb per deg F	Specific heat at constant pressure
g	ft per hr per hr	Acceleration of gravity = 4.18 × 10^8
h_c	Btu per sq ft per hr per deg F	Coefficient of convection heat transfer (McAdams)

k	Btu per sq ft per hr per deg F per ft	Thermal conductivity
p	Dimensionless	Surface emissivity (black body = 1.0)
Δp	Dimensionless	Change in value of p.
q	Btu per hr	Heat interchange between surfaces
t_s	F	Surface temperature
t_a	F	Temperature of surrounding air and surfaces
Δt	F	Temperature excess $= (t_s - t_a)$
β	1/deg F	Coefficient of thermal expansion
μ	lb per ft per hr	Absolute viscosity
ρ	lb per cu ft	Density

In calculating Gr and Pr the properties c_p, k, β, μ, and ρ are evaluated at T_{avg}.

BIBLIOGRAPHY

(1) "The Radiation and Convection from a Heated Wire in an Enclosure of Air," by T. Barratt, Proceedings Physical Society of London, vol. 28, 1916, p. 1.

(2) "Radiation and Convection from Heated Surfaces," by T. Barratt and A. J. Scott, Proceedings Physical Society of London, vol. 32, 1920, p. 361.

(3) "Separation of Radiation and Convection Heat Losses," by T. Barratt, *Engineering*, vol. 139, Jan. 25, 1935, p. 86.

(4) "Surface Heat Transmission," by R. H. Heilman, Trans. A.S.M.E., vol. 51, 1929, paper FSP-51-41, p. 287.

(5) "The Calculation of Heat Transmission," by M. Fishenden and O. A. Saunders, His Majesty's Stationery Office, London, 1932, pp. 97–100.

(6) "Separation of Radiation and Convection Heat Losses," by S. Steele, *Engineering*, vol. 139, Jan. 4, 1935, p. 19.

(7) "Emissivity of Various Surfaces," by H. C. Hottel, Chemical Engineers Handbook, McGraw-Hill Book Co., New York, and London, 1934, p. 885.

(8) "The Calculation of Heat Transmission," by M. Fishenden and O. A. Saunders, His Majesty's Stationery Office, London, 1932, p. 194.

(9) Ibid., pp. 96, 97.

(10) "The Basic Laws and Data of Heat Transmission," by W. J. King, MECHANICAL ENGINEERING, vol. 54, 1932, p. 347.

(11) "Heat Transmission," by W. H. McAdams, McGraw-Hill Book Co., Inc., New York and London, 1933, pp. 244–245.

(12) "The Heat-Insulating Properties of Commercial Steam Pipe Coverings," by L. B. McMillan, Trans. A.S.M.E., vol. 37, 1915, p. 921.

(13) "Heat Losses From Bare and Covered Wrought-Iron Pipe at Temperatures Up to 800 Deg. Fahr.," by R. H. Heilman, Trans. A.S.M.E., vol. 44, 1922, p. 299.

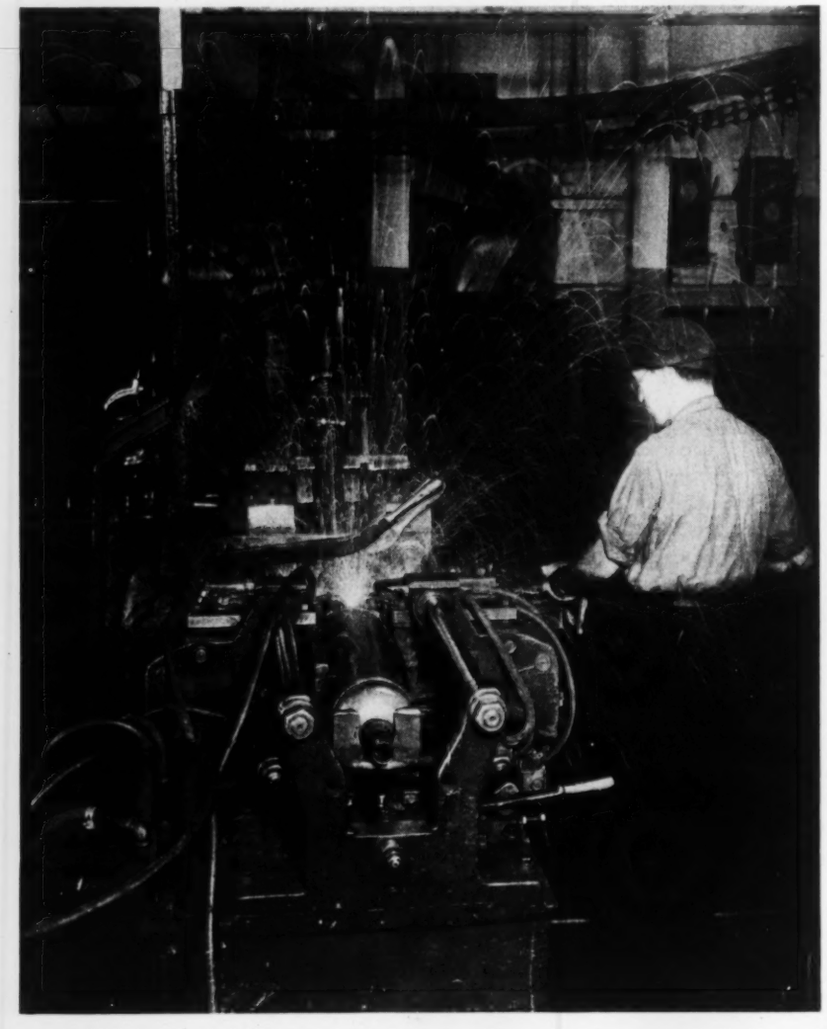
(14) "The Loss of Heat From the External Surface of a Hot Pipe in Air," by E. Griffiths and C. Jakeman, *Engineering*, vol. 123, Jan. 7, 1927, p. 1.

(15) "Heat Transmission," by W. H. McAdams, McGraw-Hill Book Co., Inc., New York and London, 1933, p. 252.

(16) "Heat Losses From Surfaces by Natural Convection," by M. Fishenden and O. A. Saunders, from "Technical Data on Fuel," edited by H. M. Spiers, British National Committee World Power Conference, London, 1932, third edition, p. 159.

(17) "Heat Transmission," by W. H. McAdams, McGraw-Hill Book Co., Inc., New York and London, 1933, pp. 243–244.

(18) Ibid., pp. 248–249.



FLASH-WELDING OPERATION ON FORD MUFFLER, WELDING INTAKE PIPE TO MUFFLER BY BUTT PROCESS

STEAM-TURBINE TESTING

A Proposal to Use Impact Pressures and Temperatures

By C. HAROLD BERRY

HARVARD UNIVERSITY, CAMBRIDGE, MASS.

IN THE course of the revision of the A.S.M.E. test code for steam turbines, there has arisen among several members of the committee charged with that task an informal discussion of the method of observing data for the computation of turbine efficiencies. This discussion has resulted in a proposal involving so distinct a departure from long-standing practice that it has seemed to us that it should be given wider consideration than the committee membership affords. Accordingly, this paper has been prepared in the hope that it will bring forth wide and thorough discussion of the idea. In order that the question may be set forth clearly, it has been presented in terms of ardent advocacy, despite the fact that the author is not fully convinced of the wisdom of the change proposed. Its status is that of a personal suggestion; it is not a committee recommendation.

It is proposed that hereafter turbine test methods shall call for the measurement of the impact pressure and temperature of the entering steam and the impact pressure of the exhaust steam. It is contended that this is a correct method, and that the use of static values is incorrect. It is further contended that the impact values can be measured with somewhat higher precision and perhaps more easily. It is conceded that the numerical change in final results will be small, but this is no argument, since the change is in the direction of a closer approach to truth and fairness, and since it is common to make provision for determining other quantities that are no larger.

It is recognized that the A.S.M.E. Test Code for Steam Turbines is concerned only with finding the actual performance of the real machine, and with correcting that performance to what it would have been if the operating conditions had been those specified in the guarantee. However, the question under discussion is so closely associated with the computation of results for the ideal engine and of the engine efficiency of the real machine that it seems proper, while the question is under consideration, to include these matters that strictly lie outside the immediate interests of the Test Code Committee.

The thermal efficiency of a turbine is the ratio of the work delivered to the aggregate energy chargeable against the turbine. The engine efficiency of a real turbine is the ratio of the work actually developed to the work that would be developed by an ideal engine receiving what the real turbine receives, and exhausting at the pressure at which the real machine exhausts.

The test data underlying these computed values are the test steam rate, together with the pressure and temperature of the steam just ahead of the main throttle valve and strainer, and the pressure prevailing at the exhaust flange of the turbine. In observing these actual operating conditions, precautions are taken to insure, in so far as may be, that the pressures measured are true static pressures.

It is here proposed that the use of static-pressure observations in this connection is incorrect, and that the values that should be observed are the impact pressure and temperature of the entering steam and the impact pressure of the exhaust steam.

Contributed by the Power Division for presentation at the Annual Meeting, New York, N. Y., December 2–6, 1935, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

BASIC RELATIONS

The steady-flow equation asserts that the sum of the work developed plus the heat given out by any steady-flow machine, real or ideal, equals the sum of the actual enthalpy drop, plus the actual drop in kinetic energy, plus the drop in potential energy due to elevation of the fluid flowing:

$$w_{12} + q_{12} = h_1 - h_2 + \frac{V_1^2 - V_2^2}{50{,}100} + \frac{z_1 - z_2}{778} \quad \ldots [1]$$

where w_{12} and q_{12} are the work and heat developed by the machine, Btu per pound of fluid flowing through it, between entrance (1) and exit (2); h is the specific enthalpy of the fluid, Btu per lb; V its absolute velocity, ft per sec; and z is elevation above a chosen datum level, ft.

The heat transfer to the outside world q_{12} is small for the real steam turbine and zero, by definition, for the ideal engine. The elevation term is small, since actual changes in elevation do not exceed a few feet, whereupon the work done by the falling of the steam is a small fraction of one Btu per pound, well below the limits of error of testing methods. For the ideal engine it may be zero by definition.

It thus appears that the work done by the steam in a turbine is given approximately for the real turbine and exactly for the ideal machine by the change in value of the quantity

$$h + V^2/50{,}100 \text{ (Btu per lb)} \quad \ldots [2]$$

so that, for the present discussion, we may call this quantity the aggregate energy of the steam at any point in its flow.

THE ENERGY SUPPLIED TO THE TURBINE

Accordingly, the energy supplied to both the real and ideal machines is the aggregate value

$$h_1 + V_1^2/50{,}100 \text{ (Btu per lb)} \quad \ldots [3]$$

Where did this come from? Obviously from the boiler plant. The heat added to water and steam in the boiler plant produces a rise in the enthalpy of the fluid, and at the same time, through expansion of the steam between boiler drum and superheater outlet, gives the steam a certain kinetic energy. In the piping to the turbine, energy is dissipated through friction and heat losses. The value [3] is the aggregate energy finally delivered to the turbine.

No portion of this aggregate energy can properly be neglected. In particular, the kinetic energy should not be neglected. The unit cost of this energy is precisely the same as the unit cost of the enthalpy. Moreover, kinetic energy is "high-grade" energy, since it is in mechanical form that is so easily frittered away through frictional losses. It may be that, far from being negligible, the kinetic energy is more important per unit than the enthalpy.

Does the turbine use this kinetic energy? Conceivably the steam might flow directly to the first-stage nozzles, whereupon the initial kinetic energy would contribute directly to the energy of the issuing jet. Usually, on the other hand, the steam is carried through tortuous passages and the velocity of approach to the first-stage nozzles may differ materially from the velocity in the supply pipe. If the kinetic energy at the nozzle approach is less than in the supply pipe, the difference appears in increased enthalpy of the steam. If it is greater, the increase has come from the enthalpy of the steam, which has been reduced through expansion of the steam. In the ideal turbine these changes will occur at constant entropy, and nearly so in the real turbine. In either case, the kinetic energy of the entering steam has been turned to useful account, in whole or in part.

THE ENERGY REJECTED BY THE TURBINE

Consistency with the foregoing point of view demands that the aggregate energy rejected by the turbine be taken as

$$h_2 + V_2^2/50{,}100 \text{ (Btu per lb)} \quad [4]$$

This is clearly the sum of the enthalpy of the exhaust steam and the leaving loss of the machine (of the whole turbine, not of its last-stage wheel).

With reference to the real turbine, this involves nothing new, but consideration of the ideal turbine introduces a difficulty. Should the ideal turbine be allowed a leaving loss? By definition, the ideal thermodynamic engine is an engine free from losses, but clearly this means losses that cannot be influenced by the designer. The enthalpy of the exhaust, for instance, is a loss for the ideal engine as well as for the real engine (the two are unequal, of course). This loss is allowed to the ideal engine because it is fixed by conditions that are not disposable by the designer. The design of the condenser and the supply of circulating water (or the pressure of the atmosphere or of process-steam apparatus) fix the exhaust conditions.

What about the kinetic energy of the exhaust steam? Long-standing practice allows the ideal machine no kinetic-energy loss in its exhaust steam. This is tantamount to defining the ideal turbine as one that discharges steam at zero velocity. Does this establish a fair criterion of excellence for the real machine?

In the case of the reciprocating engine, expansion is limited by the cylinder volume, and it was early recognized that this limit entails a large loss of available work that cannot be eliminated or even greatly reduced for a given type of engine. This loss implies no lack of skill or care on the part of the engine designer or operator. Accordingly, in setting up an ideal standard of comparison for the reciprocating engine, the incomplete expansion cycle has long been used. It includes a constant-volume process that resembles nothing that occurs in the real engine. Its use is justified by its results rather than by considerations of correspondence with reality.

It is here proposed that similar considerations apply to the ideal counterpart of the steam turbine. The real turbine exhaust departs at high velocity. This indicates a loss of kinetic energy that should have been turned into useful work. But this loss is in a measure inevitable. No designer, however clever, however free from space restrictions, could design a turbine that reduces the final steam velocity to zero. True, this loss may be large or small according as the exhaust-duct area is small or large, but the choice is determined by the purchaser's limitations rather than by any defect or excess in the skill of the designer. Thus it seems fair to treat the kinetic energy of the departing steam as a loss that is in a measure unavoidable and that should be ascribed to the ideal turbine as well as to the real turbine.

Perhaps defining the exhaust velocity from the ideal turbine as equal to the real exhaust velocity is not quite fair, in view of the fact that to some extent the magnitude of the exhaust kinetic energy is in the designer's hands; on the other hand, there is no accepted lower limit of exhaust velocity that could be set up as an ideal, and simplicity seems to suggest the use of the actual conditions.

Accordingly, it is proposed that the ideal turbine be allowed the same leaving kinetic energy that characterizes the real turbine. That is, it is proposed that the space restrictions that fix the exhaust kinetic energy of the real machine shall be imposed upon its ideal counterpart also.

METHODS OF MEASUREMENT

How can the aggregate energy of the flowing steam be evaluated? It occurs to one that we might measure the static pressure and temperature, which determine the enthalpy and specific volume of the steam, and add to this enthalpy the kinetic energy corresponding to the velocity computed from duct dimensions, rate of flow, and specific volume. It is here proposed that a simpler and more direct method be used.

What is desired is the aggregate value. We are not interested in its partition between enthalpy and kinetic energy. To this end we may measure the final pressure and temperature attained by a sample of steam that has been removed from the flowing stream and compressed isentropically to such an extent that the increase in enthalpy is equal to the kinetic energy that the steam had before it was taken from the moving stream.

It is commonly recognized that a properly oriented impact tube will read the final pressure resulting from this imaginary compression. With respect to temperature, there are reasons for believing that any thermometric instrument of appreciable dimensions extending into the stream will read the final temperature of such a compression, or something close to it. The bombardment of the thermometer by the moving steam contributes energy to it just as does the heat transfer. One has indeed seen discussions of the difficulties of measuring the true static temperature of a moving fluid stream. It appears that the enthalpy as determined by the impact pressure and the impact temperature may be taken as equal to the aggregate energy, as here defined, of the fluid in the moving stream.

Thus the present proposal boils down to this: In order to measure the aggregate energy supplied to a turbine and rejected by a turbine, the initial pressure should be measured by a properly placed impact tube, the initial temperature should be measured by a thermometric element subjected to the full impact of the moving steam, and the exhaust pressure should be measured by properly located impact tubes.

Current practice makes every effort to measure static pressures, but is somewhat in doubt with respect to the initial steam temperature. The present A.S.M.E. test code specifies the use of a temperature-measuring means inserted in a properly designed well extending a considerable distance into the supply pipe. There is reason to believe that this measures a temperature closer to the impact temperature than to the static tem-

perature. Thus current practice seems to split the difference. It indicates steam at, or close to, the impact temperature, but at a pressure lower than the impact pressure, and hence at a higher entropy than should properly be ascribed to the ideal turbine flow, and with a value of the enthalpy that is subject to question.

The measurement of the static pressure of the steam supplied demands the use of pressure piping terminating in holes perpendicular to the internal wall of the pipe and free from burrs. The holes must be of relatively small diameter, and the ratio of diameter to length of the uniform-diameter hole seems to be important. It is a fussy job to make proper pressure taps in the steam-supply pipe.

An impact tube for these conditions is a relatively simple thing. Almost any tube that terminates in an open end facing the steam flow will read the impact pressure. The shape of the tube opening is unimportant. The tubing need not be cut off precisely square. It is not necessary to aim the tube exactly into the steam velocity, since the impact tube is insensitive to angular divergence through a considerable range. There is really only one difficulty in the use of the impact tube. What should be measured is the impact pressure corresponding to the average kinetic energy of the steam. We assume that the enthalpy of the steam (based on static data) is the same throughout the pipe. This may be true. We cannot assume that the velocity is the same across the face of the flow. Just how flat the velocity front may be is a matter that may need further study. In any case, the impact-tube opening must be located at a radial distance from the axis of the pipe chosen to yield the value corresponding to the mean kinetic energy of the entire stream. The flatter the velocity front, the smaller will be the protrusion of the impact tube into the pipe, and the more sturdy can be its construction.

It seems probable that an impact tube could be arranged to include a thermocouple, so as to measure both pressure and temperature with a single device entering the pipe, replacing the temperature-measuring means now required, so that this proposal need not increase the number of devices entering into the steam pipe.

The measurement of the static pressure in the turbine exhaust is difficult. Perhaps the difficulty lies largely in convincing the skeptic that the static pressure is being measured, but yet there seems to be experimental evidence that large differences in gage readings can be had from points in the same exhaust duct.

The present A.S.M.E. test code requires the use of several gages connected to flush holes distributed uniformly around the wall of the exhaust duct. If the parties to a test agree, certain types of pressure tips may be used, located in the centers of equal portions of the cross-sectional area of the duct. Many static pressure tips have been devised that are alleged to subject their gages to the true static pressure of the steam surrounding the tip. None, so far as we know, has been universally accepted.

Is there any reason to suppose that a flush hole in the wall of a duct gives a better approximation to the static pressure than some sort of pressure tip out in the stream? If the duct is long, with smooth parallel walls, this may be true, but turbine exhaust necks are usually short and flaring. Sometimes they are sharply skewed. Sometimes they are furnished with internal stiffening ribs and/or joint flanges. Moreover, the steam enters the exhaust neck from an enormous tornado, or pinwheel, is gathered up in a sort of half volute casing, and dumped into the exhaust neck in a fashion that can neither be well predicted in advance nor detected in operation.

The A.S.M.E. test code further requires that if the several gage readings show material discrepancies, the test shall be stopped and the set-up shall be studied and adjusted until such differences no longer appear. Studies of air flow in large ducts in the laboratories of the Graduate School of Engineering at Harvard University seem to indicate that under conditions of turbulent flow there is no such quantity as *the* static pressure over any considerable area. Local values of static pressure, secured with sensitive instruments that are properly oriented at each point, vary over a wide range. If this is equally true for steam flow, no amount of the investigation called for by the A.S.M.E. test code could serve to eliminate discrepancies, unless the investigation took the form of a deliberate effort to "fudge" the pressure-tip positions to make the readings conform to a preconceived false hypothesis that they must be equal.

It may be that the impact pressure, a measure of aggregate energy, will be more uniform across the duct than the static pressure, a measure of the mode of distribution of that energy. Even so, the measurement of the impact pressure may not be any easier than the measurement of static pressure. In the exhaust duct the steam velocity is high, and the flow is highly turbulent. It may be that even at a fixed point the velocity is constant in neither direction nor magnitude. Certainly a change in turbine load must produce marked alterations in the flow pattern. The impact pressure is secured by a tube facing against the fluid velocity, and, while the permissible angular deviation is considerable, it is not unlimited. It seems possible to conceive of large directional shifts at a given point in the exhaust duct with variations in turbine load. How will it be possible to locate impact tubes?

It should be possible to design a moveable impact tube whose open end could be waggled about in all directions so as to yield the highest possible gage reading, which would doubtless be the true impact pressure sought, at the point where the tube opening is. To secure average values over a large duct it might be necessary to use many such tubes or to conduct a multi-point traverse of the duct.

Perhaps the best course is to measure the exhaust pressure with a number of impact tubes facing inward and perpendicular to the plane of the exhaust flange of the turbine, each to be connected to a separate gage, and the average of all readings to be taken to be the average impact pressure of the exhaust steam.

MAGNITUDES

What is the magnitude of the difference between the impact and static pressures? It is the "velocity pressure" that is so familiar in the measurement of air flow. For low velocities, it is readily computed by multiplying the kinetic energy by the density of the fluid. For velocities as high as are common in the steam turbine, however, this simple procedure is not sufficiently accurate, due to the relatively large changes in volume during compression. A more accurate result is obtained by interpolating in the steam tables (or reading from a suitable chart) along an isentropic path through the initial state (static p and t) to a state having an enthalpy higher than the initial value by the amount of the kinetic energy.

Table 1 presents several numerical values typical of conditions prevailing in steam-turbine supply pipes, with high velocities included to display the trend. It appears that the impact-pressure excess is often large enough to be clearly readable on ordinary pressure gages. The table also shows the rise in temperature resulting from isentropic compression.

Table 2 gives a few values for exhaust-duct conditions. It appears that, due to the low density of exhaust steam, the velocity-pressure excess is much smaller than in the case of

TABLE 1 STEAM-SUPPLY CONDITIONS

(Computed from Keenan's Steam Tables for isentropic enthalpy rise equal to kinetic energy of steam)

		Static pressure and temperature					
		100	500	600	800	1200	800
Velocity, ft per sec	Kinetic energy Btu per lb $= \Delta h$	Impact pressure, lb per sq in.	Impact temp, F	Impact pressure, lb per sq in.	Impact temp, F	Impact pressure, lb per sq in.	Impact temp, F
100	0.20	100.2	500.4	600.9	800.4	1201.9	800.4
200	0.80	100.8	501.7	603.6	801.7	1207.8	801.7
300	1.80	101.8	503.9	608.1	803.7	1217.6	803.9
400	3.19	103.1	506.9	614.1	806.8	1231.3	807.0
500	4.99	104.8	510.8	622.0	810.3	1248.9	810.9
600	7.19	107.1	515.5	632.2	815.0	1271.0	815.6
700	9.78	109.8	521.3	644.1	820.4	1297.2	821.1
800	12.77	112.9	527.7	659.2	827.0	1328.3	827.5
900	16.17	116.5	535.1	675.0	833.6	1363.8	834.6
1000	19.96	120.8	543.4	693.6	841.5	1405.7	842.6

TABLE 2 EXHAUST-STEAM CONDITIONS

(Computed from Keenan's steam tables for isentropic enthalpy rise equal to kinetic energy of steam. Exhaust steam assumed to carry 10 per cent moisture)

		Static pressure and temperature					
		0.500	79.6	1.000	101.8	15.00	213.0
Velocity ft per sec	Kinetic energy, Btu per lb $= \Delta h$	Impact pressure, lb per sq in.	Impact temp, F	Impact pressure, lb per sq in.	Impact temp, F	Impact pressure, lb per sq in.	Impact temp, F
100	0.20	0.501	79.7	1.003	101.9	15.04	213.2
200	0.80	0.508	80.1	1.015	102.3	15.20	213.7
300	1.80	0.518	80.7	1.032	102.8	15.42	214.4
400	3.19	0.531	81.4	1.059	103.7	15.76	216.4
500	4.99	0.549	82.5	1.095	104.8	16.17	216.9
600	7.19	0.572	83.7	1.137	106.1	16.75	218.7
700	9.78	0.600	85.2	1.190	107.7	17.44	220.7
800	12.77	0.635	87.0	1.255	109.5	18.20	223.0
900	16.17	0.675	88.9	1.332	111.5	19.13	225.6
1000	19.96	0.722	91.1	1.424	113.9	20.25	228.6

steam supplied. On the other hand, the rate of change of enthalpy per unit pressure change in an isentropic expansion increases rapidly as low pressures are approached, so that the enthalpy differences are large enough to be included in accurate testing.

If a pressure tip is used that responds more or less to the velocity pressure in addition to the static pressure, and if its indications are taken to be the static pressure only, then the velocity pressure excess becomes an indication of the maximum possible error. Whether the velocity pressure excess should be included or excluded is another question. The point is that if we measure one thing and call it another, we shall have a pressure error that may be as large as the velocity pressure excess, together with an enthalpy error that may be as large as the kinetic energy of the steam. Similarly with respect to temperature measurements.

IS THE RESULT A STANDOFF?

It is proposed that we charge the ideal turbine with the kinetic energy of the steam supplied to the real machine, and permit the ideal turbine to lose without charge the kinetic energy of the exhaust from the real machine. These two quantities might chance to be equal; either may be the larger. In general, the net result will be small. This being so, it appears that the choice between the long-customary method and this new proposal may safely be made on the basis of prejudice, convenience, or probable accuracy.

In testing work, precision is sought. Prejudice is ruled out. Convenience is of minor moment. Probably accuracy is to be improved even at considerable cost.

It is submitted that this proposal to use impact pressures increases the probable accuracy of results and that it also promotes convenience.

Present practice neglects the kinetic-energy terms. This custom may be merely a survival from the days when the reciprocating engine was the dominant steam prime mover. When the custom is examined critically, it has commonly been justified on the ground that in the case of an actual turbine the difference between the specific kinetic energy of supply and exhaust steam is relatively small. There may be a small loss because the departing steam moves faster than the entering steam; or the departing steam may move less rapidly than the entering steam, in which case a small portion of the work developed may be ascribed to the direct conversion of a part of the initial kinetic energy. Current practice assumes that in either case this quantity is small enough to be neglected with impunity.

The present proposal urges that nothing that is measurable can properly be neglected. It is contended that impact pressure measurements will give a closer approach to the truth.

THERMAL EFFICIENCY AND HEAT RATE

Thus far the discussion has been confined to the comparison of the actual work developed with the work that could be developed by an ideal engine. This is not all that test measurements are used for. The thermal efficiency of a real turbine is the ratio of the actual work to the energy chargeable against the machine, and the heat rate is the energy chargeable per unit of output. The energy chargeable in this sense is the sum of the heat and work that must be supplied by the feed pump and boiler plant to convert saturated liquid water at the exhaust pressure into steam at the initial conditions, figured on the same unit basis as the work developed.

This energy chargeable is the difference between the value heretofore discussed, the aggregate energy supplied, and the enthalpy of saturated liquid water at the pressure of the actual turbine exhaust. Static pressure or impact pressure?

The kinetic energy of the steam exhausting into a condenser will probably be dissipated in producing a heating effect in the circulating water. It is difficult to suppose that it will affect the final state of the condensate. To be sure, one has seen it alleged that the pressure at the bottom of a proper condenser is higher than at the top, due in part to impact effect, so that the condensate temperature exceeds the temperature of saturated liquid subject to the static pressure at the condenser inlet. Will the condensate temperature ever rise to the impact temperature? Table 2 presents numerical values.

The practice of giving the turbine credit for the enthalpy of this water is purely conventional. A condensing turbine does actually deliver water, but not enough for the boiler feed required to make steam for the turbine, since there are leakages through shaft seals and stage drains. And usually the water is returned at a temperature several degrees below the saturation temperature for exhaust static pressure. But we credit the turbine just as though it had returned the full amount of water at the saturation temperature, on the tacit assumption that water as such costs nothing, and on the ground that the temperature deficit is in no way discreditable to the turbine. Since the quantity deficit must be due to uncontrolled leakages, and since the cost of make-up water (distilled or treated) is not zero, as assumed, it would seem that this conventional practice is open to some question. The assumption that the temperature deficit is not discreditable to the turbine is justified by the device of assuming the machine to be equipped with an exhaust-steam feedwater heater through which the

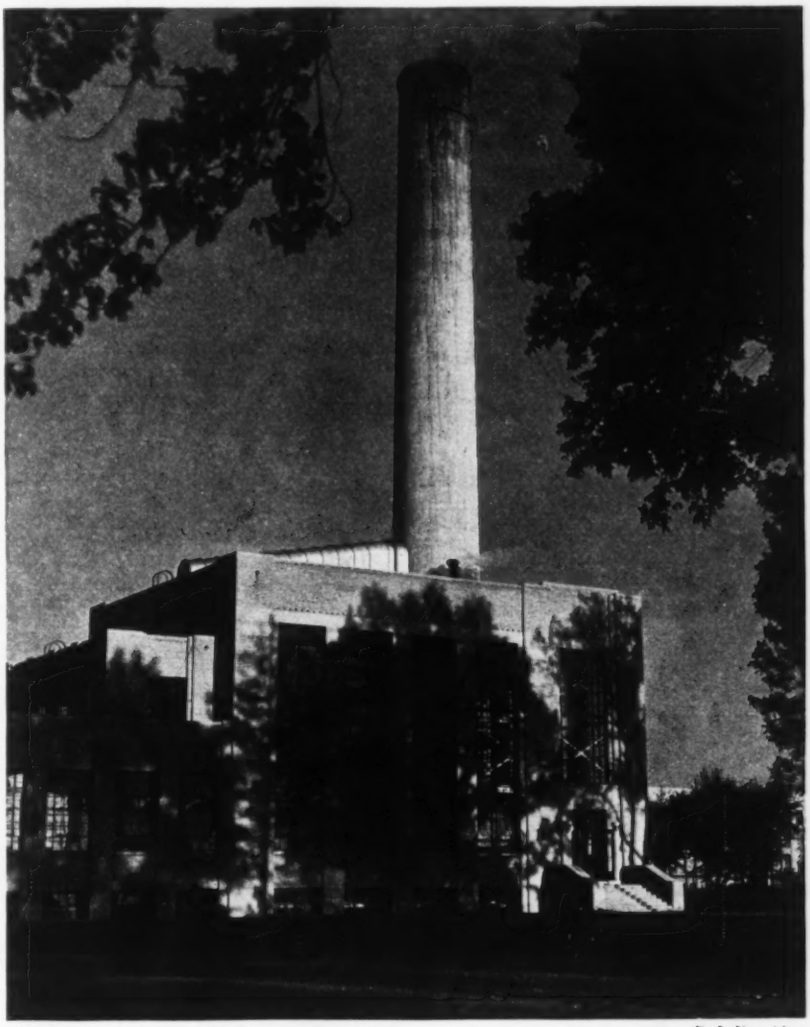
condensate and the make-up water are passed. If the heater is assumed to be indefinitely large, all of this water could be heated to the temperature of the exhaust steam. Clearly the presence of such a heater would interfere in no way with the performance of the turbine, and the omission of such a heater should not be charged against the turbine. Substantially the same assumptions support the convention as applied to non-condensing machines.

The water in this imaginary heater is to be warmed to the temperature of the exhaust steam. Static temperature or impact temperature? If steam can warm a thermometric element to what we have called the impact temperature, why can it not warm water-heating tubes to the same extent? If the kinetic energy can produce an increase in the heating effect in the circulating water, why can it not do likewise in this imaginary feedwater heater? In other words, even though, in the real unit, the final condensate temperature is not up to the impact temperature, yet it may be justifiable to assume that with proper equipment to recover all that the turbine can yield, the water starting back to the boiler plant would be at the impact temperature of the exhaust steam.

Since the difference is small (2 or 3 F for an exhaust velocity of 400 ft per sec), since one measurement is simpler than two, and since it is desired to avoid the difficulties of measuring the exhaust static pressure, it is proposed that the thermal efficiency and the heat rate of a turbine be computed on the basis of the impact pressure in the exhaust duct. It is not proposed that any temperature measurement be attempted in the exhaust duct, because this temperature is irrelevant to a turbine test, except for a test by the "heat-drop" method which may be used when the exhaust is superheated. The A.S.M.E. test code permits this method only upon special agreement by the interested parties.

TEST CORRECTIONS

An important item in the A.S.M.E. test code for steam turbines is the determination of corrections to be applied to test results for departures of test operating conditions from the conditions specified in the contract guarantee. Shall pressure and temperature specifications be interpreted in terms of static or impact values? Present practice is so thoroughly based upon static pressure that it is not customary even to mention the fact. If this proposal should prove acceptable, it would become necessary for contracts to state whether the specified pressures and temperatures are static or impact. If tests are to be conducted in terms of impact values, presumably contracts will be drawn in like terms. In any case, the computations of corrections must be in terms of the quantities which are contemplated in the guarantee specifications.



R. I. Nesmith

The Third International CONFERENCE *on* STEAM TABLES

THE Third International Steam Tables Conference was held in the United States of America during the week commencing September 17, 1934, at the invitation of the Special Research Committee on the Thermal Properties of Steam of The American Society of Mechanical Engineers. Its purpose was to improve and to extend international agreement on the properties of steam in continuation of the work of the London Conference of 1929 and the Berlin Conference of 1930. The following were present:

Great Britain

H. L. GUY, Manchester
A. C. G. EGERTON, F.R.S., Oxford
G. S. CALLENDAR, London
I. V. ROBINSON, London

Germany

PROF. DR.-ING. F. HENNING, Berlin
PROF. DR.-ING. E. SCHMIDT, Danzig-Langfuhr
PROF. DR.-ING. H. HAUSEN, Munich
DR.-ING. W. KOCH, Munich
DR.-ING. F. MICHEL, Swarthmore, Pa.

United States

DR. HARVEY N. DAVIS, Hoboken, N. J.
DR. FREDERICK G. KEYES, Cambridge, Mass.
DR. NATHAN S. OSBORNE, Washington, D. C.
PROF. JOSEPH H. KEENAN, Cambridge, Mass.
DR. H. C. DICKINSON, Washington, D. C.
GEO. A. ORROK, New York, N. Y.
DR. L. B. SMITH, Cambridge, Mass.
PROF. F. O. ELLENWOOD, Ithaca, N. Y.
PROF. R. C. H. HECK, New Brunswick, N. J.
C. B. LEPAGE, New York, N. Y.

Czechoslovakia

Represented by I. V. ROBINSON

DR.-ING. ERICH J. M. HONIGMANN, of Vienna, Austria, was present throughout the conference as a visitor.

SESSION AT WASHINGTON

The first session of the conference was opened at the National Bureau of Standards in Washington, D. C., by Dr. Lyman J. Briggs, Director of the Bureau. Greetings from the engineering societies of the United States were extended by Fred M. Feiker, secretary of the American Engineering Council. The proceedings of the conference then continued under the chairmanship of Dr. Alex Dow, chairman of the A.S.M.E. Special Research Committee on the Thermal Properties of Steam.

After the necessary formal business had been completed, a committee was formed, in accordance with the procedure followed at previous conferences, to revise and enlarge the international skeleton tables. This committee consisted of the entire British and German delegations and Messrs. Osborne, Keyes, and Keenan, with Messrs. Heck and Ellenwood as alternates for the American members.

After adjournment of the first meeting of the conference Dr. Osborne explained and exhibited the apparatus employed at the National Bureau of Standards for measurement of properties of saturated liquid water and saturated water vapor. The methods and technique of measurement were demonstrated later when Dr. Osborne and his associates executed a typical experiment.

SESSION AT CAMBRIDGE

The second session of the conference was held on Tuesday, September 18, at Massachusetts Institute of Technology in Cambridge, Mass., where the delegates were greeted by Dr. Karl T. Compton, president of the Institute. At this session Dr. James A. Beattie, associate professor of physico-chemical research, gave an address on the preliminary results of his experimental investigation of the relation between the international scale of temperature and the thermodynamic scale from the ice point to the sulphur boiling point. Afterward Dr. Keyes and Dr. Smith exhibited the apparatus and explained the methods of measurement which they used to determine the specific volume of superheated steam and compressed liquid water. Dr. Keyes showed also the apparatus he is using for measuring the Joule-Thomson coefficient and the constant-temperature coefficient.

SESSION IN NEW YORK

At the third session of the conference, which was held on Wednesday, September 19, at the headquarters of The American Society of Mechanical Engineers in New York, N. Y., Dr. Calvin W. Rice, secretary of the Society, now deceased, welcomed the delegates. The conference then adjourned subject to call by the chairman for the final session later in the week.

The committee met immediately thereafter and elected I. V. Robinson, chairman. It undertook during the next three days the revision and extension of the skeleton table of the Berlin conference in the light of the new experimental and analytical data which were presented by the various delegates.

The skeleton table adopted compares with the Berlin conference table as follows:

(*a*) The saturation pressure, enthalpy, or total heat, and specific volume of saturated liquid and saturated vapor are given at 42 different temperatures—the Berlin conference gave these values at ten different temperatures.

(*b*) The enthalpy or total heat and specific volume are given for 72 different states of superheated steam—the Berlin conference gave these values at 57 different states.

(*c*) The enthalpy or total heat and specific volume are given for 87 different states of compressed liquid water—the Berlin conference gave no values for the compressed liquid.

(*d*) At temperatures above 200 C the tolerances on properties of saturated liquid and saturated vapor are reduced to $^1/_2$ to $^1/_{10}$ of the Berlin conference values.

(*e*) Tolerances on the specific volume of superheated vapor at pressures above 100 kg per sq cm are generally about $^1/_3$ per cent of the volume—the Berlin conference values were 1 to 3 per cent.

(*f*) Tolerances on enthalpy or total heat of superheated vapor are reduced to about one-half the Berlin conference values.

The final session of the conference was held Saturday, September 22, at The American Society of Mechanical Engineers.

TABLE 1 PROPERTIES OF SATURATED LIQUID AND SATURATED VAPOR

Temp, deg C	Pressure, kg per sq cm	Tolerance, ±	Specific volume: Liquid, cu cm per g	Tolerance, ±	Specific volume: Vapor, cu cm per g	Tolerance, ±	Enthalpy or total heat: Liquid, IT cal per g	Tolerance, ±	Enthalpy or total heat: Vapor, IT cal per g	Tolerance, ±
0	0.006228	0.000006	1.00021	0.00005	206,310	210	0[a]	0	597.3	0.7
10	0.012513	0.000010	1.00035	0.00010	106,410	110	10.04	0.01	601.6	0.7
20	0.023829	0.000020	1.00184	0.00010	57,824	58	20.03	0.02	605.9	0.6
30	0.043254	0.000030	1.00442	0.00010	32,922	33	30.00	0.02	610.2	0.5
40	0.075204	0.000038	1.00789	0.00010	19,543	19	39.98	0.02	614.5	0.5
50	0.12578	0.00006	1.0121	0.0002	12,045	12	49.95	0.03	618.9	0.5
60	0.20312	0.00010	1.0171	0.0002	7,678.3	7.7	59.94	0.03	623.1	0.5
70	0.31775	0.00016	1.0228	0.0002	5,046.3	5.0	69.93	0.03	627.3	0.5
80	0.48292	0.00024	1.0290	0.0002	3,409.2	3.4	79.95	0.04	631.4	0.5
90	0.71491	0.00036	1.0359	0.0002	2,361.5	2.4	89.98	0.05	635.3	0.5
100	1.03323	Nil	1.0435	0.0002	1,673.2	1.7	100.04	0.05	639.1	0.5
110	1.4609	0.0010	1.0515	0.0004	1,210.1	1.2	110.12	0.06	642.7	0.5
120	2.0245	0.0013	1.0603	0.0004	891.65	0.89	120.25	0.06	646.2	0.5
130	2.7544	0.0016	1.0697	0.0004	668.21	0.67	130.42	0.07	649.6	0.5
140	3.6848	0.0021	1.0798	0.0004	508.53	0.51	140.64	0.07	652.7	0.6
150	4.8535	0.0032	1.0906	0.0004	392.46	0.39	150.92	0.08	655.7	0.7
160	6.3023	0.0042	1.1021	0.0004	306.76	0.31	161.26	0.08	658.5	0.8
170	8.0764	0.0053	1.1144	0.0004	242.55	0.24	171.68	0.09	661.0	0.8
180	10.225	0.007	1.1275	0.0004	193.80	0.19	182.18	0.09	663.3	0.9
190	12.800	0.008	1.1415	0.0004	156.32	0.16	192.78	0.10	665.2	0.9
200	15.857	0.008	1.1565	0.0004	127.18	0.13	203.49	0.10	666.8	0.9
210	19.456	0.008	1.1726	0.0004	104.24	0.10	214.32	0.11	668.0	0.9
220	23.659	0.009	1.1900	0.0004	86.070	0.086	225.29	0.11	669.0	0.9
230	28.531	0.010	1.2087	0.0004	71.483	0.071	236.41	0.12	669.4	0.9
240	34.140	0.012	1.2291	0.0004	59.684	0.060	247.72	0.12	669.4	0.9
250	40.560	0.013	1.2512	0.0004	50.061	0.050	259.23	0.13	668.9	0.9
260	47.866	0.015	1.2755	0.0004	42.149	0.042	270.97	0.18	667.8	0.9
270	56.137	0.017	1.3023	0.0004	35.593	0.036	282.98	0.19	666.0	0.9
280	65.457	0.020	1.3321	0.0004	30.122	0.030	295.30	0.20	663.6	0.9
290	75.917	0.022	1.3655	0.0005	25.522	0.030	307.99	0.20	660.4	0.9
300	87.611	0.024	1.4036	0.0005	21.625	0.035	320.98	0.30	656.1	1.0
310	100.64	0.03	1.4475	0.0005	18.300	0.035	334.63	0.40	650.8	1.2
320	115.12	0.03	1.4992	0.0005	15.438	0.035	349.00	0.50	644.2	1.4
330	131.18	0.04	1.5619	0.0005	12.952	0.035	364.23	0.60	636.0	1.6
340	148.96	0.04	1.6408	0.0005	10.764	0.035	380.69	0.70	625.6	1.8
350	168.63	0.04	1.7468	0.0006	8.802	0.035	398.9	0.8	611.9	2.0
360	190.42	0.05	1.9066	0.0040	6.963	0.040	420.8	0.8	592.9	2.0
370	214.68	0.05	2.231	0.021	4.997	0.100	452.3	1.5	559.3	3.0
371	217.26	0.10	2.297	0.026	4.761	0.100	457.2	1.5	553.8	3.5
372	219.88	0.11	2.381	0.034	4.498	0.110	462.9	2.2	547.1	4.0
373	222.53	0.11	2.502	0.053	4.182	0.120	471.0	3.5	538.9	4.5
374	225.22	0.11	2.79	0.15	3.648	0.120	488.0	5.0	523.3	5.0

Observed values of critical temperature: M.I.T. 374.11 C; Reichsanstalt 374.2 ± 0.1 C.

[a] By definition.

Dr. Harvey N. Davis presided at this session in the absence of Dr. Dow. The report of the committee was presented by its chairman, Mr. Robinson, and was accepted by the conference. The following resolutions were unanimously adopted:

Resolved, That it is the hope and desire of this conference that the experimental investigation of the properties of water should be continued in order to utilize the equipment and personnel of the several contributing institutions to the best advantage. It is desired that the enthalpy or total-heat measurements of superheated steam be continued at the Imperial College of Science, London, and in Czechoslovakia, and extended as far in the range of temperature and pressure as is practicable, and that other independent investigations of this field should be encouraged. The conference records its appreciation of the assurances of the British delegation that this work will be carried out.

It is desired that new measurements of the saturation pressure of steam between 0 and 100 C be undertaken at the Reichsanstalt, Berlin, and at the National Bureau of Standards, Washington, and the conference records its appreciation of the assurance of the German delegation that their section of the work will be carried out. It is desired that Dr. Koch may be able to continue his measurements of the heat capacity of the liquid and gaseous phases of water.

It is desired that the measurements on the rate of change of enthalpy or total heat of superheated steam with pressure be continued at the Massachusetts Institute of Technology, Cambridge, and that the possibility of carrying out similar measurements on the liquid phase be likewise considered, and the conference records its appreciation of the assurances of the Massachusetts Institute of Technology representatives that this work will be carried out.

It is desired that new measurements of the enthalpy or total heat of water between 0 and 100 C be undertaken at the National Bureau of Standards to provide greater accuracy in these values for use in other calorimetric measurements.

It is further desired that additional measurements of latent heat between 0 and 50 C be undertaken at the National Bureau of Standards to complete the series of these values.

An invitation extended by the Masaryk Academy of Work to hold the Fourth International Steam Tables Conference in Prague, Czechoslovakia, was accepted by unanimous vote of the conference. In accordance with the precedent established at the London and Berlin conferences the secretariat will be transferred from The American Society of Mechanical Engineers to the Masaryk Academy of Work when the business of the third conference is completed.

The skeleton table adopted by the Third International Steam Tables Conference, which supersedes the Berlin conference table of 1930, is a part of this report as Tables 1, 2, and 3. The limits fixed by its accepted values and tolerances constitute a criterion, internationally agreed upon, by which the reliability of a steam table may be judged.

CONVERSION FACTORS

The following units and conversion factors have been used in the 1934 skeleton table:

Length: 2.54000 cm = 1 in.

Mass: 453.5924 grams = 1 pound

Pressure: (*a*) One standard atmosphere = pressure of 76 cm mercury column (density 13.5951 g per cu cm, gravity 980.665 cm per sec per sec)

(*b*) One bar = 10^6 dynes per sq cm

Energy: (*a*) 1000 international steam-table calories (IT cal) = $^1/_{860}$ international kilowatthour

(*b*) 1 international electrical watt = 1.0003 absolute watts

(*c*) 1 British thermal unit = 251.996 IT cal

Temperature: All temperatures are expressed in terms of the international temperature scale. Where Kelvin temperatures were used the values were obtained by adding 273.16 to the temperatures on the international scale.

TABLE 2 SPECIFIC VOLUME OF COMPRESSED LIQUID WATER AND SUPERHEATED STEAM (cu cm per g)

(Of each pair of figures the upper represents the accepted value and the lower the tolerance (±))

Pressure, kg per sq cm	Temperature, deg C											
	0	50	100	150	200	250	300	350	400	450	500	550
1	1.00016	1.01210	1730	1975	2216	2454	2691	2928	3164	3400	3636	3872
	.00005	.00020	1	2	2	2	3	3	3	3	4	4
5	.9999	1.0119	1.0432	1.0906	433.8	484.1	533.2	581.6	629.6	677.4	725.0	772.5
	.0002	.0002	.0002	.0002	.4	.5	.5	.6	.6	.7	.7	.8
10	.9997	1.0117	1.0431	1.0902	210.4	237.6	263.3	288.2	312.7	337.0	361.1	385.1
	.0002	.0002	.0002	.0002	.2	.2	.3	.3	.3	.3	.4	.4
25	.9989	1.0110	1.0422	1.0893	1.1556	89.0	101.1	112.1	122.6	132.7	142.7	152.6
	.0002	.0002	.0002	.0002	.0003	.1	.1	.1	.1	.1	.1	.2
50	.9977	1.0099	1.0409	1.0877	1.1532	1.2495	46.41	53.12	59.05	64.60	69.92	75.10
	.0002	.0002	.0002	.0002	.0003	.0004	.07	.08	.09	.09	.10	.12
75	.9965	1.0088	1.0397	1.0861	1.1508	1.2452	27.48	33.22	37.78	41.83	45.62	49.25
	.0002	.0002	.0002	.0002	.0003	.0004	.05	.07	.08	.08	.09	.10
100	.9952	1.0077	1.0385	1.0845	1.1485	1.2410	1.3979	23.03	27.05	30.41	33.45	36.32
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.05	.05	.06	.07	.07
125	.9940	1.0067	1.0372	1.0829	1.1462	1.2369	1.3877	16.66	20.53	23.52	26.14	28.55
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.03	.04	.05	.05	.06
150	.9929	1.0056	1.0360	1.0814	1.1439	1.2330	1.3782	11.98	16.10	18.90	21.25	23.36
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.02	.03	.04	.04	.05
200	.9905	1.0035	1.0337	1.0784	1.1395	1.2255	1.3612	1.671	10.31	13.05	15.11	16.87
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.002	.02	.03	.03	.03
250	.9882	1.0015	1.0314	1.0755	1.1353	1.2184	1.3462	1.604	6.366	9.46	11.39	12.96
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.002	.013	.02	.02	.03
300	.9859	.9995	1.0291	1.0726	1.1312	1.2117	1.3327	1.557	3.02	6.98	8.90	10.35
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.002	.01	.02	.02	.02
350	.9837	.9975	1.0269	1.0698	1.1272	1.2054	1.3207	1.521				
	.0002	.0002	.0002	.0002	.0003	.0004	.0007	.002				
400	.9814	.9956	1.0247	1.0670	1.1234	1.1994	1.3097					
	.0002	.0002	.0002	.0002	.0003	.0004	.0007					

Compressed liquid water ← | → Superheated steam

The specific volume of the liquid at 4 C, at a pressure of one atmosphere is 1.000027

TABLE 3 ENTHALPY OR TOTAL HEAT OF COMPRESSED LIQUID WATER AND SUPERHEATED STEAM (IT cal per g)

(Of each pair of figures the upper represents the accepted value and the lower the tolerance (±))

Pressure, kg per sq cm	Temperature, deg C											
	0	50	100	150	200	250	300	350	400	450	500	550
1	.023	49.97	639.2	663.2	686.5	710.1	734.0	758.0	782.4	807.2	832.3	857.8
	.005	.03	.5	.5	.6	.6	1.2	1.2	1.2	1.2	1.2	2.0
5	.120	50.05	100.11	150.92	681.9	706.7	731.5	756.1	780.8	805.9	831.3	856.9
	.005	.03	.05	.08	1.0	1.0	1.2	1.2	1.2	1.2	1.2	2.0
10	.240	50.15	100.20	151.00	675.1	702.1	728.0	753.5	778.9	804.5	830.1	855.9
	.005	.03	.05	.08	1.0	1.1	1.2	1.2	1.2	1.2	1.2	2.0
25	.599	50.45	100.46	151.21	203.6	687.8	718.0	746.3	773.3	800.0	826.5	852.6
	.005	.03	.05	.08	.1	1.1	1.2	1.2	1.2	1.2	1.2	2.0
50	1.20	50.96	100.90	151.58	203.8	259.2	698.4	732.9	763.1	791.6	819.9	847.3
	.01	.03	.05	.08	.1	.1	1.2	1.2	1.2	1.2	1.2	2.0
75	1.79	51.46	101.34	151.95	204.1	259.2	672.6	717.6	752.1	783.2	813.1	841.8
	.01	.03	.05	.08	.1	.1	1.2	1.2	1.2	1.2	1.2	2.0
100	2.39	51.96	101.78	152.32	204.3	259.2	320.5	699.5	740.0	774.5	806.0	836.1
	.01	.03	.05	.08	.1	.1	.3	1.2	1.3	1.3	1.3	2.0
125	2.98	52.46	102.22	152.69	204.6	259.3	319.9	676.7	726.9	765.2	799.1	830.3
	.01	.03	.05	.08	.1	.1	.3	1.2	1.3	1.3	1.3	2.0
150	3.57	52.96	102.65	153.06	204.8	259.3	319.3	646.8	712.1	755.3	791.8	824.4
	.01	.03	.05	.08	.1	.1	.3	1.5	1.3	1.3	1.3	2.0
200	4.74	53.96	103.57	153.82	205.2	259.4	318.4	393.1	676.5	733.4	776.0	812.0
	.01	.03	.05	.08	.1	.1	.3	.8	2.0	2.0	2.0	2.5
250	5.90	54.96	104.46	154.57	205.8	259.5	317.6	387.6	622.5	707.5	758.8	798.9
	.01	.03	.05	.08	.2	.2	.3	.8	2.5	2.5	2.5	3.0
300	7.05	55.96	105.35	155.33	206.2	259.7	317.0	384.0	524.5	677.5	739.7	
	.01	.03	.05	.08	.3	.3	.3	.8	3.0	2.5	2.5	

Compressed liquid water ← | → Superheated steam

ENERGY CONVERSION TABLE

Units	Joules	Kg-m	Ft-lb	Int j	Int whr	IT cal	Btu	Lb per sq in. × cu ft	Atm × cu dm
10^4 joules	10000	1019.72	7375.62	9997	2.77694	2388.17	9.4770	51.2196	98.6923
100 kg-m	980.665	100	723.30	980.371	.272325	234.20	.92938	5.02293	9.67841
10^4 ft-lb	13558.2	1382.55	10000	13554.1	3.7650	3237.9	12.8491	69.4444	133.809
10^4 int. joules	10003	1020.02	7377.8	10000	2.7778	2388.9	9.4799	51.235	98.722
10 int whr	36011	3672.1	26560	36000	10	8600	34.1275	184.446	355.40
10^3 IT cal	4187.3	426.99	3088.4	4186.05	1.16279	1000	3.9683	21.447	41.3255
10 Btu	10551.8	1075.99	7782.6	10548.7	2.93019	2519.96	10	54.046	104.138
10^3 lb per sq in × cu ft	195238	19908.7	144000	195179	54.216	46626	185.027	1000	1926.85
100 atm × cu dm	10132.5	1033.23	7473.35	10129.5	2.81374	2419.8	9.6026	51.898	100

1 liter × atm = 1.000027 atm × cu dm 1 kg per sq cm × cu m = 10000 kg-m

On the basis of these values, the accompanying conversion factors and tables have been derived.

Volume conversion factors:

1 cu ft = 28316.8 cu cm = 28.3161 liters

Specific volume:

1 cu ft per lb = 0.062428 cu m per kg
1 cu m per kg = 16.0185 cu ft per lb

PRESSURE CONVERSION TABLES

Units	Atm	Kg per sq cm	Lb per sq in.	Bar	Mm Hg
1 atmosphere	1	1.033228	14.6959	1.013250	760
1 kg per sq cm	0.967841	1	14.2233	0.980665	735.559
10 lb per sq in.	0.68046	0.70307	10	0.689476	517.149
1 bar	0.986923	1.019716	14.5038	1	750.062
1 meter Hg	1.31579	1.35951	19.3368	1.333224	1000

Robert Dudley Smith

OUR INTERNATIONAL ACCOUNTS

By RALPH E. FREEMAN

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE excess of United States merchandise exports over imports for the first eight months of 1935 was only $27,279,000 as compared with nearly ten times that sum for the corresponding period of 1934. During this same period we imported more than one billion dollars of gold. This means that we had to find nearly a billion dollars of foreign money (or claims to money) to make payment for an enormous excess of imports over exports (including both merchandise and gold).

From what transactions did we secure this foreign buying power? At first thought the answer might appear to be—from interest and dividends on our foreign investments. We know that last year we received $327,000,000 on this account. On the other hand we also know that we paid out last year $344,000,000 on account of the expenditures of American tourists and our immigrant and charitable remittances abroad. Since there is no reason to suppose any considerable change in the relative amounts of these items since last year, our question remains unanswered. We are forced to the conclusion that we have been borrowing, or (what amounts to the same thing as far as our national payments are concerned) that foreigners have been depositing money in our banks, buying our securities, and repurchasing their own. During the first eight months of 1935 there was a large net inflow of capital into the United States amounting to somewhere in the vicinity of a billion dollars.

In each of the past thirteen years the Bureau of Foreign and Domestic Commerce of the United States Department of Commerce has published a document entitled, "The Balance of International Payments of the United States," which gives an itemized account of the inpayments and outpayments of the country during the preceding year. Since this publication enables us to answer questions similar to that just presented, it is worthy of the careful attention of all those who are interested in the commercial and financial transactions conducted by the people of this nation with the people of other nations. The latest issue (Trade Information Bulletin No. 826) presents the record more clearly and more exactly than any of its predecessors.

This publication also contains a summary of our international transactions of previous years from which the accompanying table is constructed. All items are balances, that is, net differences between inpayments and outpayments. In 1934, for instance, receipts from exported merchandise amounted to $2,133,000,000 while payments to foreigners for imports amounted to $1,655,000,000, leaving a net inpayment of $478,000,000 as shown in the table. Take the case of long-term investments. The table shows that in 1934 there were $202,000,000 more of such investments made in this country by foreigners than we made in other countries. The table also shows that in every year Americans have spent more to travel in foreign countries than foreigners have spent to travel in the United States: In 1934 this excess was estimated at $220,000,000.

All the items in the first group are those in which inpayments have been greater than outpayments during the years under consideration, while the second group lists those items on account of which our inpayments have in most years been less than our outpayments. It is not to be supposed, however, that all the individual items will remain in these categories in the future. The third group contains items most of which on balance change from year to year more readily than items in the other groups. In 1928, 1931, and 1933, for instance, we exported gold, while in 1929, 1930, 1932, and 1934 we imported gold. On the whole it will be seen we have been net exporters of capital, though in 1934 we imported $184,000,000 of short-term funds, and during the last four recorded years we imported

THE UNITED STATES BALANCE OF INTERNATIONAL PAYMENTS[1]

(In millions of dollars, as estimated by the Department of Commerce)

		1928	1929	1930	1931	1932	1933	1934
1	*Foreign countries undertook to pay us for:*							
	a Our merchandise export surplus	1037	841	782	334	289	225	478
	b Their war debts to us	207	207	241	113	99	20	1
	c Interest and dividends on our loans to them	534	565	616	536	393	384	327
	Totaling	1778	1613	1639	983	781	629	806
2	*Payment was made to us in part through:*							
	a Shipping and freight services	80	66	96	72	45	16	35
	b Tourist expenditures abroad	552	638	602	456	375	221	220
	c Immigrant remittances abroad, charity, etc	276	265	215	202	163	132	124
	d Government and miscellaneous transactions	145	197	97	93	67	45	39
	Totaling	1053	1166	1010	823	650	414	340
	Leaving a net current balance still due us, amounting to	725	447	629	160	131	215	466
3	*This had finally to be met through:*							
	a Currency shipments to us	40	15	—20	10	80	90	48
	b Gold shipments to us	—272	120	278	—176	11	—173	1217
	c Silver shipments to us	...	...	...	...	...	...	86
	d Short-term credits by us	188	80	485	709	409	385	—184
	e Long-term loans by us	662	137	267	—219	—217	—49	—202
	Totaling	618	352	1010	326	283	253	965
	Residual item	107	95	—381	—164	—152	—38	—499

[1] Arrangement of items according to *The Annalist*, March 30, 1934, p. 510.

Eighth of a series of reviews of current economic publications affecting engineering, prepared by members of the Department of Economics, Massachusetts Institute of Technology, at the request and under the sponsorship of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

long-term capital. In more cases a capital import involves an export of securities and vice versa. A minus sign signifies that the direction of the payment was the opposite of that indicated in the heading of the group in which the item is included. For this purpose the residual item belongs in group 3.

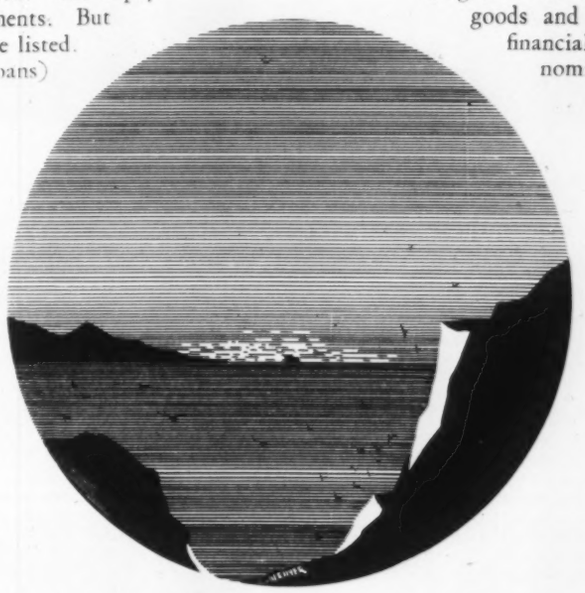
The net payments made to foreigners on account of the second group did not place them in possession of enough dollars to enable them to meet their obligations arising out of the first group. Moreover, in every year but 1929 they had to find additional dollars to meet obligations arising out of one or more transactions in the third group. In 1933, for instance, they had to pay for $173,000,000 more gold shipped to them than they shipped to us and to find an additional $49,000,000 for long-term investments in the United States. This was achieved through the shipment to us of $90,000,000 of our currency and the borrowing of $385,000,000 on short-term account.

It should be noted that a payment of debt by foreigners may be affected by the repurchase of securities previously sold to us. It has the same effect on the balance of payment as an importation of capital by us. The sums recorded as long-term capital imports in 1931, 1932, and 1933 originated largely in this fashion. It should be noted also that an increase or decrease of the deposits held by the banks of our country in the banks of another is equivalent to international borrowing and lending of short-term funds. The imports of currency represent chiefly the repatriation of money taken to Canada, Mexico, and other foreign countries by our tourists. Since bank credit is used in international transactions even to a greater degree than in domestic transactions, the amount of international currency movement is normally very small.

Two further observations should be made regarding the balance of payments. The first is that the large sums against the "residual item" bear witness to the inadequacy of our information concerning international financial transactions. The item of $499,000,000 called residual in 1934, for instance, is thought to represent for the most part the return of funds previously expatriated in anticipation of American currency devaluation and the inflow of foreign-owned funds as a result of economic and political uncertainty abroad; but no statistical evidence could be secured to support this conclusion. The second observation is that the account necessarily balances, since by one means or another foreigners managed to secure the dollars necessary to settle for all the items listed as due us for goods, services, loans, and so forth. The inpayments were equal to the outpayments. But not all their obligations to us were listed. The intergovernment debts (war loans) and other foreign loans made by us upon which interest or principal was defaulted were not included in the list. The shrinkage in terms 1*b* and 1*c* after 1930 is largely attributable to the fact that our foreign debtors for one reason or another failed to meet their obligations.

"The exporter, the importer, the banker, the investor, and the student of world affairs all watch the ebb and flow of the international movement of funds." Yet in spite of the interest and importance of this document, it is probably more often misinterpreted than any other government report that is issued for public perusal. The most misleading feature of general comments on the report is their persistence in referring to a net inflow of funds arising from a single account or group of accounts as "favorable" or "unfavorable." Any one item has to be studied along with the other items and interpreted in the light of the international position of the nation. It is obvious that in the absence of abnormal gold imports such as occurred last year and is occurring at the present moment, our international position demands a surplus of merchandise imports over exports to facilitate the receipt of interest and dividends on our foreign investments. That we have been for the past twenty months a net importer of capital and a net exporter of goods is clearly an anomalous position. A nation can hardly continue to sell more abroad than it purchases and at the same time leave its foreign customers with less power to buy its goods. If our export surplus of merchandise is to continue, we must lend—that is, import securities in exchange. And yet the continual granting of loans to purchasers cannot go on indefinitely, for when the loans begin to bear interest, inpayments become greater, requiring the possession of additional dollars by foreigners and increasing the difficulties of adjustment.

The perplexities and uncertainties of America's international financial position are nowhere revealed more clearly than in this annual publication of the Department of Commerce. The extent to which domestic policy must be held responsible for international difficulties and what change we should make in that policy to effect a solution cannot be determined without a careful study of our international accounts. As pointed out in a recent publication of the Guaranty Trust Company of New York, "It must be remembered that to a certain extent our recovery is dependent on conditions abroad; and to that extent a sound domestic recovery program should consider measures that would tend to permit foreign countries to meet their obligations to us without ceasing to purchase our goods and without unduly straining their financial resources and upsetting their economic organization."



ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The Gyroplane

THE article gives a brief history of the development of this machine called by its inventor, E. Burke Wilford, the Wilford gyroplane. It is stated that although considerable engineering refinement is still necessary, the work already accomplished has established future possibilities of the gyroplane. The principles of operation of this machine were set forth in MECHANICAL ENGINEERING, December, 1932, p. 862.

As one of the possible structural difficulties is mentioned the fact that the rotor takes all stresses in bending. Attention is called to the fact, however, that by means of the so-called "centrifugal relief" surprisingly thin metal propeller blades have been successfully employed. It is also believed that the gyroplane can be made partially flexible, as the only limitation to flexibility is the necessity of clearing the tail surfaces as in landing and taxiing. The author does not believe that the presence of gyroscopic forces and couples represent an insuperable difficulty. (Alexander Klemin, Daniel Guggenheim School of Aeronautics, New York University. In *Aero Digest*, section of *Aviation Engineering*, vol. 26, no. 2, February, 1935, pp. 40–42, illustrated)

The Auxiliary Sailplane

THE auxiliary sailplane, designed by Sir John Carden, is in reality a self-starting glider. The engine is a single-cylinder Villiers two-stroke of 249 cu cm capacity. It is of inverted type which was adopted in order to raise the center of the crankshaft, thus giving the necessary air-screw clearance with small overall height.

The mounting of the engine is simple. Two tubes having a diagonal bracing member run to the crankcase and V-tubes to the cylinder head, so that the whole system is perfectly triangulated and a rigid mounting is provided.

The sailplane is of all-wood construction. A portion of the wing section is of the highly cambered type, but at the root, where the wing joins the fuselage, the lower surface is flat. Two objects are achieved by this arrangement: First, the spars can be made a good deal deeper at the root, where extra strength is required (the wings being pure cantilever), and second, a better shape of joint is secured, thereby probably reducing interference drag between root and fuselage. Toward the top the wing section begins to change, and at the tips it becomes one of small chord and thickness and of reflex curvature.

The aerodynamic reasons for this progressive change of section and, incidentally, also angle of incidence, is to insure that the center portion of the wing shall stall first. A gentle dropping of the nose is further insured by the fact that the trailing edge is nearly straight and the leading edge swept back to it so that a certain measure of the stability of the tailless airplane is achieved. The ailerons are differentially operated, so as to avoid adverse yawing moments. The machine was designed for a cruising speed of approximately 35 mph. The tank contains enough fuel for a little more than one-half hour flight, as the engine is to be used merely to attain altitude. (*Flight*, vol. 27, no. 1376, May 9, 1935, pp. 508–509)

APPLIED MECHANICS

Hysteretic Influences on the Whirling of Rotors

AFTER a short summary of the known facts concerning elastic hysteresis, an explanation is given of the way in which it can produce whirling when the shaft is running above its critical speed. Elastic hysteresis causes a deflection of a revolving shaft subject to a transverse load, and a summary is given of the laws of elastic hysteresis found by Kimball, and Kimball and Lovell, from tests which made use of this phenomenon.

Clamping fits, couplings, and the endwise friction in the bearings can act in a similar manner, and attention is drawn to several important points which should be borne in mind when designing a high-speed rotor. The effects of hysteresis forces on the stability of the shaft are discussed, with an approximate quantitative theory. The paper concludes with a bibliography.

In the course of his experiments the author has often observed the sustained transient, but has never been able to control it with certainty. It would appear when it was not wanted, and refused to do so when it was desired to have it. A series of experiments was therefore instituted.

It was found in these experiments that a transient of small amplitude would generally decay even with the shaft running above its critical speed. But if the transient increased to about $^1/_2$ in. radius, it would often be maintained at that amount, and if it increased still further it would grow until the shaft struck the guard.

Attempts were made to verify the endwise friction effect by adding friction grips through which any lengthwise movement had to take place. Sometimes these grips did seem to promote the sustained transient, but on the whole these tests must be taken as inconclusive. Since the sustained transient runs exactly at ω_0, and since its speed difference as compared with the shaft can be timed over a long interval, it enables that speed to be accurately determined for the conditions under which the shaft is then running.

The accuracy of the vibration methods, or one using the decaying transient to show the speed error, is limited because the difference between the vibration frequency and that set by the standard vibrator, or by the measurement of shaft speed, has to be determined within the short interval during which the transient decays.

Because of the restraining action of the bearings on the directions of the shaft ends, the critical speed often increases with the amplitude of the whirl. With the shaft speed only a little above the critical, this increase of stiffness will prevent a growing transient from getting beyond the amplitude which brings the critical speed up to the running speed, for beyond that point the hysteretic effects would be reversed. If the transient grew right up to this point, it would run at the same speed as the shaft.

The observed sustained transients were

always seen to rotate backward relatively to the shaft; consequently their growth was not checked by the change of critical speed just mentioned. This change of stiffness must be borne in mind when the critical speed is measured; the method already referred to would give the value applicable to the particular deflections which existed during the test, and would not necessarily agree with the results of other tests using different deflections. (Paper by Prof. David Robertson, abstracted from preprint The Institution of Mechanical Engineers, 21 pp. of which the last 2 are bibliography on elastic hysteresis and whirling)

ENGINEERING MATERIALS

New Heat-Resistant Alloy

A NEW heat-resistant alloy consists of iron-chromium-aluminum and contains 37.5 per cent chromium and 7.5 per cent aluminum. It is melted in the high-frequency furnace, and its ingots are rolled to rod or ribbon, or swaged to wire for use in electric-furnace resistor elements. On life test and in furnace operation the new alloy has many times the useful life of the standard nickel-chromium alloy. The temperature range for operating the metallic-resistor type of electric furnace has thereby been raised to 2300–2400 F. Details of life testing, properties, and behavior are given in the paper.

The alloy is readily melted with the oxyacetylene torch. It is important to maintain an oxidizing film and not to allow the metal to take up carbon by using an excess of gas.

As regards microstructure, samples are prepared for microscopic examination by the usual procedure of the metallographic laboratory. The ordinary etching reagents do not attack the alloy, though acid ferric chloride does produce an etch. Warm 40 per cent sulphuric acid has been found to be suited to the development of the structure.

The rolled and swaged alloy is exceptionally free from the coarser oxide inclusions while the etched structure resembles that of alpha iron with a small amount of carbide. Heating produces a recrystallization and continued heating soon produces a stable structure which remains essentially fine-grained throughout life. The swaged wire and the wire after burnout at 2600 F are illustrated in the original article. A photomicrograph shows the edge of the wire with its roughened surface and shows that there is no oxygen penetration along grain boundaries, or "internal oxidation." (Paper before the American Society of Metals, Sept. 30 to Oct. 4, 1935, by S. L. Hoyt and M. A. Scheil, 17 pp., 5 figs. Abstracted from preprint)

FOUNDRY

German Progress in Automobile Castings

AS regards the casting of piston rings, the author's opinion is that single cast-iron rings are preferable to the method of casting in multiple bushes, and that the centrifugal-casting process is superior in the case of alloyed piston rings. In this process the rings are cast in the shape of a bush from which the rings are obtained by machining.

One of the advantages of centrifugally cast rings is the uniformity of the material throughout the entire section. In stationary casting, for the single ring at least one gate is required and if the sections is small a riser is also necessary. At these points the ring will remain liquid for a longer period and cool more slowly, so that it acquires a different structure and becomes softer. Rings which are out of true may be the result.

As regards alloyed additions it has been found that eutectic graphite generally contained batches of ferrite which proved detrimental to the durability of the casting. The formation of eutectic graphite is therefore to be avoided. It has been also found as a result of numerous experiments that the mileage of a piston ring is improved by a well-marked phosphide network. But as phosphorus reduces the tensile strength of the metal, there are certain limits to its use. The manganese content is kept at the highest limit, from 0.8 to 1.0 per cent on an average.

It was formerly held that in order to render a piston ring resistant to wear it was only necessary to provide for an essentially pearlitic structure. Experience, however, has shown that pearlite alone is not the determining factor. The advantage of a phosphide network has already been mentioned. Moreover, a fine-grained and, above all, resistant structure has proved to be necessary, for piston rings in internal-combustion engines are now subjected to temperatures which are often considerable.

The examination of a single ring showed that at each heating of 24-hr duration and at increasing temperature, a constantly increasing fall in tension occurred. Up to 300 C there was a tension drop of about 10 per cent, which may still be regarded as quite tolerable. Above 300 C, however, the pressure falls rapidly, the loss at 400 C being already about 60 per cent. When the pressure is greatly reduced, however, a piston ring no longer fulfills its allotted function of maintaining tightness. The rings either permit the passage of oil or allow the hot gases to sweep past them, so that the oil film is destroyed and the rings wear out rapidly or seize.

The resistance of piston rings to heat (according to recent measurements, temperatures of 250 to 350 C, and sometimes even higher are encountered) depends on the resistance of the carbides contained in the cast iron, among other factors, their size and arrangement. Pearlite consists of a lamellar arrangement of iron-carbide (cementite, Fe_3C) and ferrite.

The formation of the pearlite is also of importance; coarsely lamellar pearlite (bush casting) is much less resistant than finely lamellar pearlite or sorbite, such as is met with in extremely fine-grained cast iron (single or centrifugal casting). The resistance of the carbides to heat can be materially improved by the addition of carbide-forming or carbide-promoting elements. These include chromium, molybdenum, vanadium, tungsten, arsenic, antimony, and bismuth. In experiments, chromium, vanadium, and particularly, molybdenum have so far given the best results. Experiments with tungsten are still proceeding.

In order to determine their heat-resisting properties, the finished piston rings are placed in a cylinder of suitable diameter and heated for a given period, generally 24 hr, at 200, 300, or 400 C. The loss in tension in percentage of the initial tension may be regarded as the measure of the heat-resistance. It is interesting to observe that a piston ring heated to a certain temperature, e.g., 320 C, suffers a fall in tension after only a short period, but then maintains a constant level, that is to say, that the piston ring, once it has suffered the tension drop corresponding to the temperature, retains its tension in relation to these temperatures, i.e., it remains resistant to heat. When heated at higher temperatures, e.g., 340 to 380 C, a further fall in tension then occurs, and, as before, follows a nearly straight line. The dependence of the heat-resistance upon various alloy constituents is shown in Fig. 4, in the original article, the high value of the chromium and molybdenum alloys being immediately obvious. The test temperature was the same for all rings, namely, 340 C. Similarly, all test rings had the same dimensions.

Curves are given in the original article showing the effect of various additions

on the loss in tension of a standard bush-cast ring, attention being called to the fact that the manner in which the tension is applied may affect the heat resistance of a piston. In Germany efforts are being made to discover a definitely reliable method for the testing of piston rings.

Reference is made to attempts to produce rings by embedding bronze members in cast-iron members in such a manner that the bronze will take care of the actual running conditions while the cast iron will provide the resistance to heat. In Germany no appreciable advantages have been gained by this method. Moreover, the view is being increasingly adopted that for a good piston ring a suitable cylinder surface is necessary. (W. A. Geisler in *Foundry Trade Journal*, vol. 53, no. 990, Aug. 8, 1935, pp. 97–101 and 104, illustrated)

HYDRAULICS

Coefficient of Roughness of Conduits Under Pressure

IN 1923 Strickler demonstrated the possibility of applying to all profiles of canals and pipes a formula established by Manning for open canals, namely, $v_m = kR^{2/3}J^{1/2}$.

In this formula v_m denotes average velocity, k is the coefficient of roughness dependent on the nature of the pipe, R the hydraulic radius, and J loss of power per unit of length. While this is a practical formula that is extensively applied, the choice of the proper coefficient of roughness presents certain difficulties.

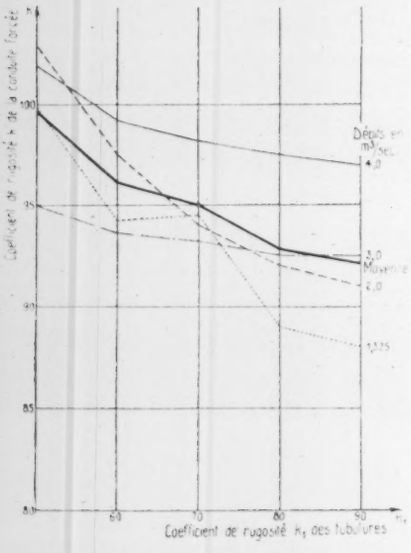


FIG. 1 D'ORSIERES CONDUIT ON WHICH THE COEFFICIENT OF ROUGHNESS HAS BEEN DETERMINED

(Ordinates = coefficient of roughness k; abscissas = coefficient of roughness k_1 of tubes; *Débits en m³/sec.* = output in cubic meters per second; *Moyenne* = average roughness.)

To cite an example, the author claims that he is not at all certain that this coefficient of roughness has been properly determined for all-welded conduits. Also, for conduits under pressure, used at Wäggital, consisting of welded and riveted sections, only the average coefficient of roughness has been determined applicable neither to a conduit entirely welded nor to one entirely riveted. It is because of this that the author made use of an opportunity to determine the coefficient of roughness of a conduit. This conduit happened to be practically rectilinear. Some of the results are presented in Fig. 1, where the coefficient of roughness k in the straight sections is expressed as a function of the coefficient of roughness k_1 in the tubes. (First installment of a serial article by G. Mathys in *Bulletin Technique de la Suisse Romande*, vol. 61, no. 17, Aug. 17, 1935, pp. 193–195, 3 figs.)

MACHINE-SHOP PRACTICE

Cutting-Speed-Tool-Life Curve

FOR rating the machinability of a metal, with tool life as a basis, it is advisable to determine the cutting-speed-tool-life curve for desirable conditions, rather than to base conclusions on the tool life for one cutting speed determined for each of the variables. Results of tests are presented in this paper to show that this straight-line curve, as plotted on log-log paper, may be changed in its vertical position on the scale and in slope from the horizontal, if any one of the factors, such as type of tool material, tool shape, the shape of the cut, the analysis or structure of the material that is cut, and the cutting fluid, are changed.

Four brands of high-speed steels are shown to produce four distinctly different speed-tool-life curves when cutting a given steel under otherwise the same conditions. Curves of different height and slope are obtained when cutting steels of different analyses with the same tool material and tool shape, and when the heat-treatment of steel of a particular analysis is changed. If the tool angles, comprising the back-rake, side-rake, side-cutting angle, and the tool nose radius, are changed different cutting-speed-tool-life curves are thereby obtained.

It is shown further that, when cutting one steel with each of several cutting fluids with a constant tool shape and a deep thin cut, one set of cutting-speed-tool-life curves is obtained. When the cut is shallow and thick but of the same cross-sectional area, distinctly different curves are obtained for each of the same group of cutting fluids. Lastly, it is shown that, when cutting a given steel with a given tool and size of cut, individual cutting-speed-tool-life curves are obtained for each of several cutting fluids. Those cutting fluids having supposedly superior lubricating properties appear to have less slope from the horizontal and are, therefore, superior for metal cutting where a long tool life accompanied by a low cutting speed is desired.

Among the conclusions attention is called to the following:

The addition to an emulsion of colloidal graphite suspended in water produces slightly favorable tool-life values but inferior finish. The work, operator, and machine were left extremely dirty, however.

When colloidal graphite suspended in oil is added to the soluble oil before reduced with water to make an emulsion, the slope of the cutting-speed-tool-life curve with the horizontal is reduced, while the constant remains practically the same. When colloidal graphite of not less than 0.150 per cent by weight is added to the emulsion, the cutting speed for a given tool life is increased about 10 per cent and the tool life for a given cutting speed is increased about 100 per cent. This emulsion was clean and proved to be satisfactory as a cutting fluid.

For commercial use it seems desirable that the colloidal graphite carried in oil be added to the soluble oil at the time of its manufacture. Some types of soluble oils proved to be poor carriers of the graphite.

When colloidal graphite is added in increased quantities to a plain mineral oil, the resulting cutting-speed-tool-life curve becomes more horizontal, showing the exponent to be reduced with a slight change in the value of the constant. Maximum benefits in cutting speed or tool life are obtained when the percentage of colloidal graphite by weight in the mineral is 0.153. For a given tool life, an increase in cutting speed under these conditions averages 20 per cent. For a given cutting speed, the tool life increases 400 to 600 per cent. The addition of the colloidal graphite to the mineral oil darkened the color of the oil, but it did not prove to be objectionable, as the machine and work were left clean as the oil ran off. Only about 3 per cent

of the colloidal graphite was found to settle out of the oil on standing for a period of three weeks. (O. W. Boston, W. W. Gilbert, and C. E. Kraus in a paper before the American Society of Metals, Sept. 30 to Oct. 4, 1935, 24 pp., 12 figs. Abstracted from preprint.)

MACHINE-SHOP PRACTICE

Coefficients of Friction Between Silk and Cotton Belts and Various Pulley Materials

SMALL flat endless belts are now available having a thickness of only 0.020 in. if made of silk, and 0.040 in. if made of cotton fabric. The method of construction makes the joint almost imperceptible, which, coupled with the extreme flexibility obtainable by employing thin material, enables the belts to be used with very small pulleys provided that the coefficient of friction between belt and pulley material is sufficiently high.

The belts are suitable for light duties, in which connection several pulley materials

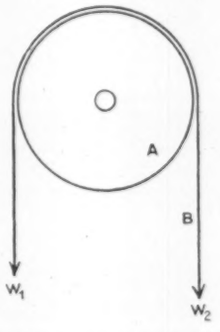


FIG. 2 DIAGRAM TO ILLUSTRATE METHOD OF MEASUREMENT ADOPTED

and methods of construction not used in larger power work are available. The values of the coefficients of friction between these belts and some of the possible pulley materials are not given in textbooks and pocketbooks, and may therefore be of interest.

The method of measurement adopted in obtaining the values given in the accompanying table is shown in Fig. 2. Here A is the pulley over which the belt B is placed. W_2 is a constant weight, and the value of W_1 is increased until the belt just slips round the pulley. The limiting coefficient of friction μ was calculated from the following well-known equation

$$W_1/W_2 = e^{\mu\theta} \quad \ldots\ldots\ldots [1]$$

and since $\theta = \pi$ radians in this case

$$\mu = 0.733 \log_{10} W_1/W_2$$

COEFFICIENTS OF FRICTION BETWEEN COTTON AND SILK BELTS AND VARIOUS PULLEY MATERIALS

No.	Pulley material	Coefficient of friction μ: Cotton belt 0.040-in. thick	Coefficient of friction μ: Silk belt 0.020-in. thick
1	Molded red rubber as used for bungs	0.59	0.59
2	Bakelite molding, straight knurl, $^1/_{16}$-in. pitch	0.51	0.48
3	Natural cork	0.46	....
4	Thin felt lining on wood	0.45	0.35
5	Brass, straight knurl, $^1/_{16}$-in. pitch	0.44	....
6	Untreated cotton tape on wood	0.38	0.34
7	Bakelite cloth gear, 47 D.P.	0.34	....
8	Boxwood, smooth turned	0.26	0.25
9	Birch, smooth turned	0.26	0.31
10	Bakelite molding, smooth, but fingermarked	0.24	0.30
11	Bakelite molding, polished	0.16	0.26
12	Balata, pressed smooth	0.15	....
13	Steel, polished, normal pulley surface	0.14	0.15

All the pulleys tested were about 1 in in diameter.

The effect of the character of the pulley surface is illustrated by comparing the results of tests 2, 7, 10, and 11, with bakelite material. In test 2 the edges of the knurl were fairly sharp, giving a good grip. In test 7 the edges were machined, and therefore smooth, but the uneven surface gave a higher effective coefficient than was obtained with the smooth pulley in tests 10 and 11. With smooth, molded-bakelite pulleys the polished condition, giving the lowest value of μ, should always be assumed in calculations.

For many purposes rubber pulleys are convenient. They are readily obtainable as moldings, and the high coefficient of friction obtainable enables much smaller sizes to be used than is possible with bakelite or metal pulleys. However, rubber pulleys must not be heated appreciably above atmospheric temperature, or allowed to come into contact with oil. (E. C. W. in *Machinery* (London), vol. 46, no. 1194, Aug. 29, 1935, p. 663)

Hard-Facing With Boron

THERE are two processes of doing it called respectively by their inventor, "sweat on" and "cast on."

"Sweat on" boron, as the name implies, is applied by bringing the surface of the parent metal to a sweating heat when the boron crystal preparation in finely divided form (60 mesh or finer) congeals with the parent metal surface to form a level, abrasive-resistant, corrosion-resistant, heat-resistant skin.

"Cast on" boron on the other hand, is heated up and poured to fill whatever space there may be between an easily constructed mold and the parent-metal part to which it is applied. This method forms a layer or shell that is solid and firmly amalgamated with the parent metal, and which may be ground to a highly polished surface.

It is not alone the hardness of the crystals nor their resistance to corrosion which gives the "sweat on" process its efficiency. Other hard facings in use today consist of a continuous mass or shell of wear-resistant material that is welded to, or amalgamated with, the parent metal, while in the "sweat on" process the crystals do not fuse or amalgamate with each other to form a solid mass. On the contrary, the outer skin of the parent metal to which "sweat on" has been applied becomes impregnated with myriads of tiny, hard, wear-resisting, and corrosion-resisting particles that are solidly attached to the parent metal, yet do not hamper any further heat-treatment or working of the parent metal. As the parent metal expands or contracts, or is hammered or formed, each crystal travels along with the unit of parent metal to which it is attached and remains unchanged and ready to function.

To apply "sweat on" it is necessary to make a stiff paste of the "sweat on" powder and a mixture of sodium silicate (water glass) and water, then brush or spatula-spread a relatively thin layer of the paste over the surface to be covered. When the parent metal beneath the paste is brought to a sweating heat, the operation is complete.

Another method of applying the "sweat on" is to bring the surface to be covered to a sweating heat and sprinkle or dust on the dry powder until the surface is covered to the desired thickness. But this method is, in a general sense, less economical, slower, and not so sure to produce the absolutely level overlay that is most frequently required.

Several layers can be applied to the same surface, but the multiple layers do not increase the efficiency of the process in direct proportion to their number. (Miles C. Smith, *American Machinist*, vol. 79, no. 16, July 31, 1935, pp. 548-550, illustrated)

MANAGEMENT

Checking Power-Tool Maintenance Costs

THE system consists of three simple elements. First is a requirement that the minute a portable electrical tool shows the slightest sign of trouble, its operator must return it to the toolroom and exchange it for one in perfect working condition. Second, every tool receives a thorough inspection, relubrication, and overhaul at least every six months. Third, a tool-by-tool record is kept of all maintenance.

An extensive table in the original article gives data on 17 tools taken from the record book. The original article also gives details of the system of checking and an example of how such questions are answered, as, for instance, "What is it worth to mount a portable drill on a bench?"

Altogether the costs add up to $11.70 per tool per year for the straight portables as compared to $6.20 for the bench drills, a difference of $5.50 per tool per year. In addition, it is fair to charge at least $3 per tool-hour for having to hold a tool out of service. Therefore, it is safe to say that, on the basis of these particular tools, the benches save $11.50 per tool per year on total costs of forced outages. This, in a five-year tool life, would amount to $57.50, to be added to the extra production speed that is the real reason for mounting drills on benches for appropriate operations.

Other tables give such data as tool-by-tool tabulation of time units of outages, maintenance materials costs units, and total forced outage hours and costs of 17 portable electric tools, as well as a comparison of three drills mounted on benches that move on casters, and two of the same capacity used as straight portable drills. (*Mill and Factory*, vol. 17, no. 1, July, 1935, pp. 29–35, illustrated)

MARINE ENGINEERING

Fuel Consumption and Maintenance Costs of Marine Engines

THE items affecting a comparison of the different types of propelling machinery are as follows: (1) Cost of machinery (referred to later); (2) bunkers; (3) engine-room staff wages and provisions; (4) engine-room stores, lubricating oil, and water; and (5) boiler, machinery repairs, and survey.

Basing the costs, for example, on a proposed vessel of 15,500 tons displacement, making loaded passages of 5000 miles, with allowance of 15 per cent surplus bunkers, it is estimated that the vessel will maintain an average speed of $11\frac{3}{4}$ knots loaded and 13 knots in ballast under all sorts of weather conditions.

TABLE 1 COMPARATIVE COSTS PER MILLION TON-MILES

Propulsion machinery	Boiler and machinery repairs and survey, £	Engine stores and water, £	Engine-room staff wages and provisions, £	Bunkers, £
Diesel	3.03	1.35	5.96	16.90
Turbine (oil)	2.92	1.06	5.70	28.40
Steam reciprocating (oil)	2.50	1.13	5.35	34.42
Turbine (coal)	3.13	1.10	8.58	25.30
Steam reciprocating (coal)	2.71	1.18	8.25	30.70

For various types of propulsion machinery the performances in ton-miles per year are as follows: Diesel 462×10^6, turbine (oil) 446×10^6, steam reciprocating (oil) 440×10^6, turbine (coal) 431×10^6, steam reciprocating (coal) 424×10^6.

The comparative costs per million ton-miles are shown in Table 1.

Fuel consumption is the most important factor affecting the relative running costs of vessels fitted with different types of machinery, the next most important factor being the capital cost. A comparatively small gain in fuel economy will generally prove far more important than considerable differences in relative repair costs or other factors which have been referred to. The cargo-carrying capacity may be greatly affected by the fuel consumption, depending upon the trade route, bunkering conditions, and steaming radius, while these conditions will also similarly affect the actual fuel costs. It is therefore not intended by the authors that any broad conclusions as to the most suitable type of machinery for all classes of vessels should be drawn from the analyses. Each particular case must be dealt with on its own merits. It should, therefore, be noted that in the case of Diesel machinery this important factor of fuel consumption can be predicted with no appreciable margin of error, but with steam machinery an allowance must be made to cover variations in performance due to the human element, which so largely controls the running of this type of machinery, and also for variation in performance caused by the state of boiler surfaces and conditions of superheat, feed temperature, and vacuum. (Paper by L. J. LeMesurier and H. S. Humphreys before the North East Coast Institution of Shipbuilders, abstracted through *Journal of the American Society of Naval Engineers*, vol. 47, no. 2, May, 1935, pp. 306–313)

MOTORCAR ENGINEERING

The de Normanville Gear Box

THE de Normanville gear box has been accepted for use by the Humber car after an extensive trial. It consists of two engaged groups of six planet wheels, each group with one driving and one loose sun wheel and one annulus. There is therefore the usual number of planets and sun wheels for a four-speed epicyclic design, but only two annuli instead of four. Every element is carried by ball and roller bearings.

The author presents a general analysis of the epicyclic gear design showing how the de Normanville train has helped to solve many difficult problems. An instance of this is the method used in altering the bearing speeds and bearing loads for a given ratio and input torque. With the ordinary epicyclic train the planet bearing speed is materially above that of the engine. In the de Normanville there is a reduction of 50 per cent from engine speed.

The diagram of force for the low-gear planet bearing loads shows the benefits of the gear due to interengagement of the planet wheels.

The system of control is of particular interest. This system is hydraulic. A worm-driven plunger-type pump, which runs at one-sixth of engine speed, is located in the front of the box. This feeds oil to an accumulator mounted at the side of the box, which overflows when the desired pressure is reached, and passes along the center of the main shaft, and so by centrifugal force to lubrication duties. For the indirect gears, opposed brake levers are employed and are fitted with self-balancing V-shaped metal shoes.

The details are given in the original article and reference will be made here to one feature only, an ingenious detail of control which is the single ball valve with duplicated seats for the inlet and outlet of oil, and the hollow plunger which concurrently serves as a leak by-pass. With hydraulic control, it is necessary for the designer to assume that every valve may permit a minute leakage. When running, for example, on top gear,

it is necessary to assume that the valve controlling any other gear is subject to a slight leak, caused, let us say, by a microscopic defect on the valve seat. In time, such a leak, if it were not by-passed, would bring another gear into concurrent operation. With the de Normanville valve, leakage can only generate enough pressure against the shoulder of the tappet to lift the tappet and so give free passage to the sump.

The gear underwent extensive tests before being adopted, a part of this test being its use in the Sahara trip. (*The Automobile Engineer*, vol. 25, no. 334, July, 1935, pp. 245–246)

POWER-PLANT ENGINEERING

The Bleeder Type Turbine

OF PARTICULAR interest in this kind of turbine is the method of controlling the admission of steam to the low-pressure section. There are two such methods differing radically in their mode of operation and efficiency. These are throttle and nozzle control. The throttle-control method of governing entails passing the whole of the steam which enters the low-pressure section through a valve, the opening of which is controlled by a pressure regulator, usually through the medium of an oil relay system. As a result when little steam is passing into the low-pressure section very considerable throttling loss takes place at this point and a portion of the available heat drop in this section is lost, the steam entering the low-pressure nozzles at a considerably reduced pressure.

A typical Mollier diagram for a bleeder turbine with throttle control of the low-pressure section is shown in Fig. 3 for different loads on this section.

The line *AB* shows the heat drop available in the high-pressure section down to 30 lb per sq in gage, and assuming for purposes of illustration an efficiency of 75 per cent. The line *AD* shows the state of the steam during its expansion to the bleeder pressure and the point *D* lying on the 30-lb pressure line shows that the steam retains about 70 F of superheat. Even with the low-pressure section fully loaded, a small throttling loss takes place through the control valve. This is represented on the diagram by the horizontal line *DE* corresponding to a pressure drop of, say, 2 lb per sq in. and the line *EH* will represent the expansion of the steam in the low-pressure section of the turbine, the point *H* lying on the design exhaust-pressure line corresponding to, say, 28 in. vacuum.

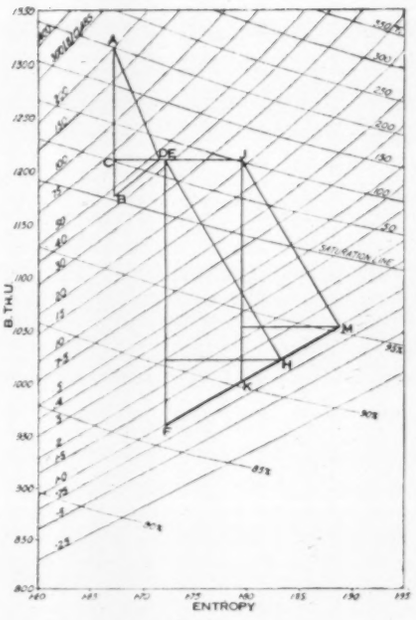


FIG. 3 MOLLIER DIAGRAM FOR A BLEEDER TURBINE WITH THROTTLE CONTROL OF THE LOW-PRESSURE SECTION FOR DIFFERENT LOADS

If, however, the steam quantity passing through this section is reduced to, say, one-half, due, perhaps, to a decrease in electrical load or to an increase in the bleeder quantity, the throttling loss through the control valve will be large and as represented by the horizontal line *DJ*, the absolute pressures at *E* and *J* being proportional to the steam quantities passing in each instance. The available heat drop in the low-pressure section will be reduced to *JK*, the amount lost by throttling is *EF* — *JK*, and the point *M* shows the state of the steam entering the condenser.

The nozzle-control method of regulating the admission of steam on the low-pressure section consists essentially of a disk with ports which moves some of the nozzles admitting steam to this section and regulates the area of nozzles in operation in proportion to the steam quantity passing. A characteristic Mollier diagram for the two sections of a bleeder-type turbine with nozzle control of the low-pressure section is given in the original article. With this arrangement there is no throttling loss. The full bleeder pressure exists in front of the nozzles for all conditions of loading, and for partial loads the available heat drop in this section is considerably higher than with the throttle-control method.

The relative efficiency of these two methods of control is illustrated in the original article which shows the characteristic change in efficiency that occurs with different loadings of the low-pressure section, the actual efficiencies shown being of the order which would obtain in this section of a small turbine.

It must be noted that the Mollier diagram shows the behavior of each pound of steam and takes no cognizance of the quantity actually in use. Also in the foregoing examples it has been assumed for simplicity that the vacuum remains constant for all loadings of the low-pressure section. Actually, the vacuum would improve at lighter loads provided, of course, that a constant quantity of cooling water is used in the condenser.

As regards the power available from process steam it is possible to show on a chart the power that can be generated by the expansion of the process steam from various initial steam conditions to various bleeder pressures. Such a chart is shown in the original article.

It should be realized that the heat units transferred to the process are derived almost entirely from the latent heat of the steam and not from the sensible heat. From the table of temperature and latent heat of saturated steam at various bleeder pressures given in the original it appears that the latent heat is lower at the higher pressures, and, notwithstanding an increase in sensible heat, that the total heat contents do not appreciably vary over the range of bleeder pressures shown.

The real limiting factor determining the choice of the bleeder pressure is almost always the temperature of the process, and the pressure used should only be slightly above that which corresponds to this minimum temperature. From an illustration in the original article it will be noted that with initial steam conditions of 200 lb gage 200 F and a bleeder pressure of 40 lb gage each 10,000 lb of steam would generate approximately 245 kw. By reducing the bleeder pressure to 20 lb gage the same quantity would generate 327 kw, or about 33 per cent greater output. Therefore, for any given electrical load exceeding 327 kw in this example, the lower the process pressure the less would be the steam that would be required to be passed to the condenser (with a corresponding saving in fuel consumption).

In an entirely new installation where it is possible to fix the most suitable initial conditions the question of the initial steam pressure should be most carefully considered.

From a purely thermodynamic point of view, the higher the pressure adopted the higher will be the efficiency, but with a smaller plant the use of extreme pressures should be undertaken with

caution and only after fully considering the difficulties that must be met.

As a general rule the bleeder steam superheat of 50 F has been suggested for a large proportion of bleeder installations. There are, however, many instances where the exceptional layout of the plant warrants a different degree of bleeder-steam superheat.

It may be assumed for all practical purposes that within limits a change of initial superheat will result in the bleeder superheat being changed by an approximately equal amount, so that if the bleeder superheat is required to be raised or lowered, it is only necessary to increase or decrease the initial superheat by the same amount. It is, therefore, possible to fix approximately the initial superheat for any bleeder-steam superheat by means of the chart, it being merely necessary to assume a final superheat of 50 F as a preliminary step and after arriving at the corresponding initial superheat to increase or decrease this superheat by the amount that the selected bleeder-steam superheat exceeds or is less than 50 F. For example, for pressures of 250 lb gage and 40 lb gage and a final superheat of 100 F the initial superheat would be 174 + 50 F or 224 F. (First two installments of an article published by C. G. Lloyd in the *Textile Recorder*, abstracted from a reprint in *The Metropolitan Vickers Gazette*, vol. 15, no. 265 and 266, May and June, 1935, pp. 278–280 and 295–297, illustrated)

Producer-Furnace-Fired Lancashire Boiler

THE producer described is of the Wollaston type and is applied to fire a Lancashire boiler 30 ft × 8 ft 6 in., one of a battery of four. Labor with this arrangement as compared with hand firing is greatly reduced and so are the stand-by costs (reduced by two-thirds). An important advantage of the producer system is its flexibility.

Sudden demands for steam are common in many industries, e.g., bleaching, brewing, and paper-making. Such demand is at once indicated by fall of pressure when the fireman opens the dampers, fires new fuel, and after perhaps ten or fifteen minutes, during which he has no doubt excited the attention of the smoke inspector, he begins to recover pressure. To meet such conditions it is not uncommon to have one or more extra boilers maintained in banked condition until the call for extra steam comes. Latterly, systems of steam accumulators have been sometimes installed.

Fig. 4 is a chart representative of those taken daily from the plant illustrated,

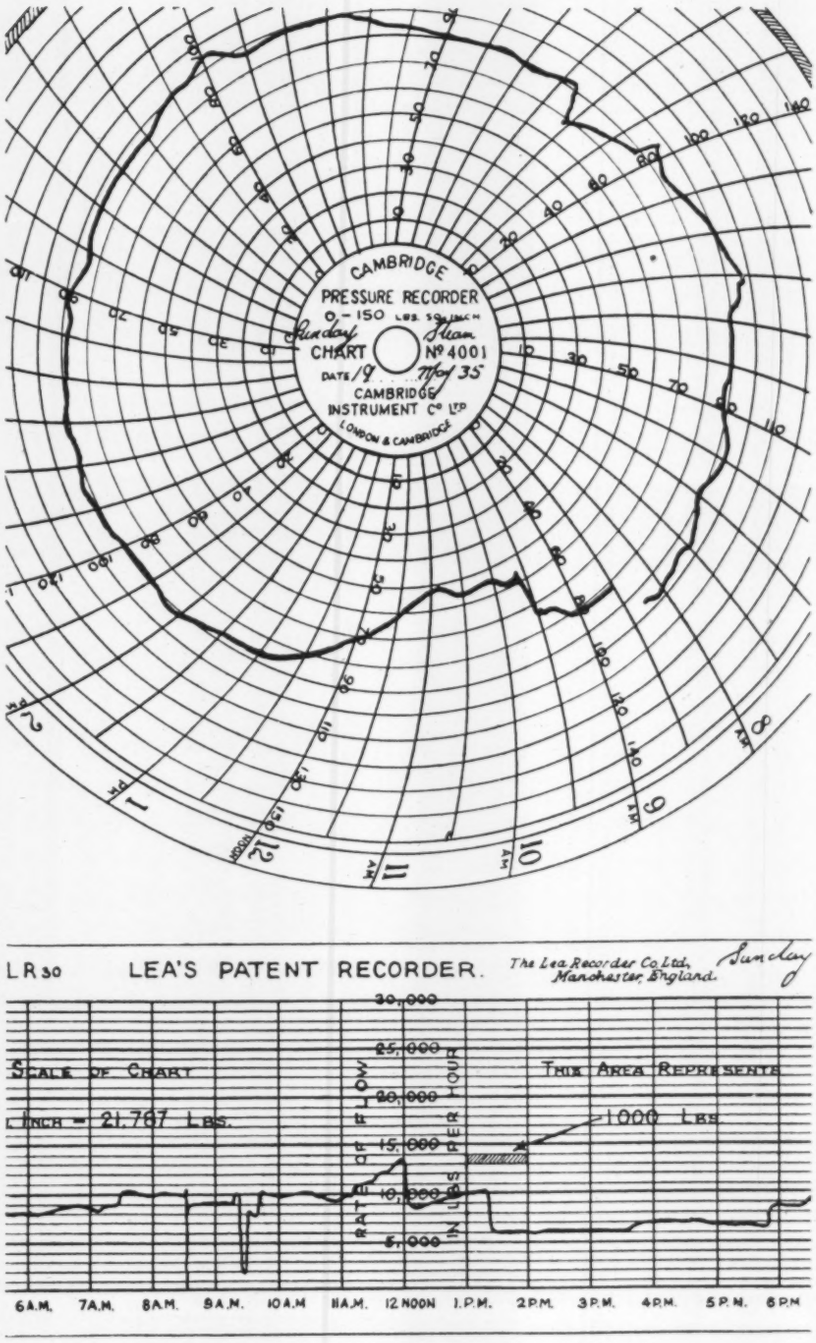


FIG. 4 CORRESPONDING PRESSURE AND FLOW CHARTS

which is at a large institution and hospital. Prior to the installation, under summer load conditions it was always necessary to have at least two boilers under steam. Since May last one boiler only has been in service. This boiler would normally be rated at about 8000 lb of steam per hour. It will be seen from the chart that on this particular day, between the hours of 5 a.m. and 1 p.m. the steam demand fluctuated between 8000 and 13,500 lb, and that between 10 a.m. and noon the rate of evaporation increased from 10,000 to 13,500 lb per hr, the steam pressure rising from 60 to 80 lb through this period. Note effect of increased demand between 11 a.m. and noon.

This incidental overload of 68 per cent is attained by the simple manipulation of a light master valve on the fan, and, though not in this particular case automatic, is so in other smaller installations. The master valve in these cases is con-

trolled either by thermostat or simple pressure device.

A further notable feature of producer firing is that between half-load and 30 per cent overload the normal thermal efficiency and CO_2 readings remain practically constant. (*Mechanical World*, vol. 98, no. 2536, Oct. 9, 1935, pp. 126-127, 2 figs.)

Colloidal Treatment of Boiler Feedwater

ONLY the outstanding points of this extensive article are here reported. It is now generally accepted that adherent boiler scales are formed in situ, that is, they are not first precipitated in the bulk of the boiler water, afterward baking onto heating surfaces. The theory is that a bubble of steam is first formed on the boiler plate. At the edges of the bubble in contact with the plate there will be a very thin film of water in contact with the boiler plate on one side and with steam on the other. This film will rapidly become superheated, resulting in the precipitation of such salts as calcium sulphate, owing to their reduced solubility at increased temperatures. A ring of scale will in this way form around the circumference of the bubble. It will be recognized that if a solution of any salt is saturated in respect to that salt, anything which tends to reduce the solubility of the material will cause precipitation to occur, resulting in the gradual building-up of crystals.

It was also previously considered that the presence of an acid, as, for instance, carbon dioxide, in the water was essential for corrosion to take place; but it is now found that what is known as the solution pressure of a metal may be sufficient in itself when the water with which the metal is in contact contains dissolved oxygen. The presence of acidic substances certainly assists corrosion; but in the absence of dissolved oxygen such corrosion is checked after a period by polarization, due to the formation of a protective film of hydrogen on the metal surface.

The new treatment involves the use of pyrogallol which as an oxygen absorbent is familiar in connection with flue-gas testing. The substance can be formed under high temperature from gallic acid by the removal of one molecule of carbon dioxide. Pyrogallic acid, or pyrogallol, is not an acid in the true sense of the word, being more in the nature of a phenol, and it is not harmful to boiler metal. Upon oxidation, that is, when oxygen is absorbed from the feed, pyrogallol in alkaline solution gives a substance called hexahydroxytriphenoquinone. The formation of the pyrogallol, far from being prevented by high temperature, is assisted by it, and while the hexahydroxytriphenoquinone may be decomposed after prolonged subjection to high temperature, even then the oxygen will not be liberated in the free state to do damage to the boiler. Apart from oxygen absorption the use of certain organic substances is beneficial, as apparently a layer of large organic molecules is adsorbed by the surface of the iron, raising the electrical resistance at the interface of metal and solution.

Some figures are given as to the cost of the application of the treatment. The author states that blowoff valves do not remove the suspended matter efficiently and apparatus is being brought out to secure improvement in this direction. (J. S. Merry, paper read before the Manchester Association of Engineers, England. Abstracted through *Blast Furnace and Steel Plant*, vol. 23, nos. 5 and 6, May and June, 1935, pp. 331, 332, 342 and 411, 412, and 418, illustrated)

RAILROAD ENGINEERING

Balancing of Three-Cylinder Locomotives

IN the opinion of the author the failure within recent years of the balancing of locomotives to keep up with design is to be found in most cases in the excessive percentage of reciprocating weight which is balanced. The old rule of two-thirds as the correct proportion is usually more than is required with the long and heavy engines of today.

Reciprocating masses are balanced in order to check nosing movements and to eliminate small variations in the drawbar pull, but the large moment of inertia of big modern types causes a greater resistance to the nosing oscillations, and the balancing of a lesser percentage of the reciprocating masses will give steady riding. Three-cylinder engines with cranks at 120 deg or thereabouts have a greater nosing moment than two-cylinder engines with reciprocating weights of the same weight per set, but this is usually counteracted by the smaller size of the reciprocating parts of a three-cylinder engine of equal power.

In locomotives of the three-cylinder type there is a complete balance of the horizontal forces and the secondary forces resulting from the obliquity of the connecting rod. These locomotives have, however, an unbalanced horizontal couple which can be countered in this case only by revolving masses placed in the wheels. A formula for this horizontal couple is given in the original article.

In general three-cylinder locomotives have a small hammer blow per axle for the engine as a whole, but are characterized by a high blow per wheel which makes a reduction in the balanced percentage of the reciprocating weights most desirable.

The best modern practice in Great Britain balances 25 to 40 per cent of the reciprocating parts but on the Continent scarcely more than 25 per cent of modern passenger engines are balanced, and the proportion gets down to as low as 10 per cent. The rules of the Japanese Government Railways for three-cylinder locomotives allow for a maximum hammer blow of 15 per cent of the static load on each wheel at 60 mph, which results in an average of only 20 per cent of the reciprocating weights being balanced.

Calculation is given for certain factors in the balancing of the three-cylinder locomotives applied particularly to the Argentine 4-8-0 locomotive. In this locomotive the cylinders are not set at an angle of exactly 120 deg, the inside unit being inclined to the horizontal at 1 in $6\frac{1}{4}$ and the outside pair at 1 in 15; which introduces a complication into the calculations in that the balance weights on opposite sides will not be the same.

Contrary to what might be expected at first sight, the size of the balance weights in the driving wheels (where all three cylinders drive on one axle) is not reduced by prolonging the inside crank webs to form a balance weight for the webs, pin, and revolving portion of the inside connecting rod. This method, however, may have some advantage by balancing these masses in their own plane and eliminating the bending stress in the axle due to the rotation of the inside parts. Here again the author considers the Argentine locomotive referred to and goes through calculations of hammer blows and certain other factors. (F. L. Baxter, *The Engineer*, vol. 160, no. 4150, July 26 1935, pp. 84-85)

SPECIAL MACHINERY

Dust Filter for Mine Air

AN abstract of this article is given because of the growing importance of the art of filtering air in connection with the prevention of such diseases as silicosis.

The present filter belongs to the class of flannel filters and is based on a theory that the flannel does not act solely as a fine screen. Dust may be divided into two categories—that capable of impingement onto a surface and that not capable of impingement.

The author believes that contact with the material used, such as flannel, is brought about largely by the microscopic antennas in it momentarily and periodically assuming the same velocity as certain particles of fine dust passing through the pores of the material. If all the dust is not caught by a screening action, but by deposition on the fibers of the flannel, filtering can be accomplished without passing air through the flannel and by passing it between two or more flannel surfaces compressed together.

Experiments made suggested that the principle of the streamline filter might be successfully applied here. In this filter invented by Doctor Hele-Shaw the flannel surfaces are conveniently arranged in the form of a series of rings, the internal diameter of which is that of the duct supplying the air and the external diameter sufficient to give ample area for filtration at a reasonable pressure. A model was constructed and tested and the results of the test given in the original article. It is said that the estimated size of filter to handle 2000 cu ft per min of air issuing from a 15-in. pipe would be about 2 × 3 ft. The control of filtering is by suitable adjustment of the pressure of the rings, and as the filter clogs with dust the pressure can be gradually eased so as to maintain the volume. (Paper by H. W. Adler and J. P. Rees before the Chemical, Metallurgical, and Mining Society of South Africa, abstracted through the *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. 35, no. 12, June, 1935, pp. 366–370)

STEAM ENGINEERING

Back-Pressure Steam Engine With Constant Pressure Regulation of the Heating Steam

THIS article refers to a 350-kw Sulzer back-pressure steam engine installed in an artificial-silk factory. Referring to Fig. 5, steam flows from the superheater of the 35 atm steam boiler *A* through a separator *E* at a pressure of 30–32 atm gage and a temperature of 350 C. When it reaches the steam engine it expands to a heating-steam pressure of about 0.6 atm gage. By means of a bypass equipped with an automatically operated throttling valve the steam can also go directly from the boiler into the heating system.

The heating steam pressure is maintained at a constant level by means of a steam-pressure governor N_2. This, by means of a control valve, acts on the speed governor *H* of the steam engine and in this way controls the load in accordance with the pressure in the heating-steam system. A second control valve operated by the steam governor N_2 acts through the piping *T* on the distant speed control of an older steam engine operating from a 12-atm gage piping. In the original design the steam governor controlled also the valve governing the admission of live steam.

All of this control apparatus is so connected that if pressure in the heating-steam system begins to fall off the governor N_2 first increases the output of the new steam engine *B*. When the maximum output of this engine has been attained some of the load is thrown on the old engine operating from the 12-atm gage system, and if even this does not provide enough output to maintain the desired steam pressure the steam-inlet valve is set into operation.

Since it may happen that the steam output from the boiler is not sufficient to provide the desired additional steam a second steam-supply valve is provided making it possible to feed the heating-steam system from the 12-atm gage piping. (This valve is not shown in the illustration.)

In this way the heating-steam pressure is maintained at a constant level under any conditions that may come up, while the steam engines are made to carry the full load before any live steam is expanded to heating-steam pressure by passing it through one of the pressure-reducing valves. The reason why this arrangement is so important is that the power demand of this particular factory is always greater than the total output, so that in addition to the electrical energy generated from the steam, it is necessary to buy outside current. Since, however, the plant's own energy cost is only a fraction of that of outside current, the economy of operation is at a maximum while the maximum possible power output is extracted from the heating steam.

If the pressure in the heating system rises while the demand for heating steam falls off, the regulating apparatus works in reverse. First, the pressure-reducing valve leading from the 12-atm gage system is closed; next, the valve *S* is closed, whereupon the load on the old machine is thrown off and finally the new machine *B* is set to carry a smaller load. The regulator operates precisely and reliably in the manner described, but the experience of the first few months of operation has indicated that in order to obtain good, steady operation of the boilers, it is desirable that the steam engine should be regulated not by the exhaust steam pressure but by the boiler pressure, and that its load be so set that the boiler pressure remains at all times at 35 atm gage.

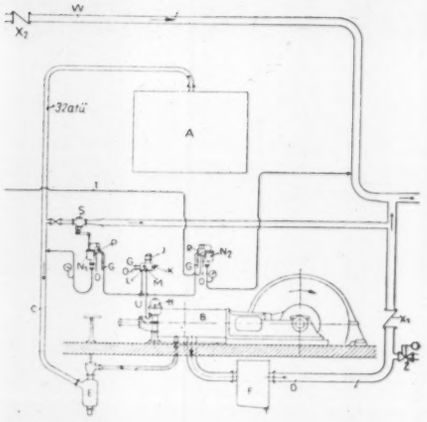


FIG. 5 350-KW BACK-PRESSURE STEAM ENGINE

(*A* = steam boiler; *B* = the new steam engine; *C* = steam supply pipe 32 atm gage; *D* = exhaust steam pipe 0.6 atm gage; *E* = separator; *F* = exhaust-steam oil separator; *G* = pressure oil pipe; *H* = speed governor; *J* = electric motor for operating distance between governor from the switchboard; *K* = handwheel for hand speed control; *L* = lever setting for control output at given inlet steam pressure; *M* = lever setting for pure speed control; N_1 and N_2 = pressure governors; *O* = oil overflow; *P* = pressure relay; *R* = double relay; *S* = hydraulically controlled outflow valve; *T* = oil control pipe leading to the old steam engine; *U* = three-way cock; *W* = exhaust steam pipe from the old steam engine; X_1 and X_2 = valves; *Z* = safety valves.)

In order to achieve this regulation a second steam-pressure governor N_1 is introduced. The operation of this governor is controlled by the pressure in the live-steam pipe leading to the steam engine and it acts on the speed governor *H* of the steam engine operating the throttle valve. This throttle valve comes into action when the steam engine set for full cutoff cannot handle all the steam that is generated. In such a case the excess amount of steam flows through valve *S* into the heating-steam system. The governor N_1 therefore belongs to the boiler, as it automatically controls the pressure therein. A hand-operated speed control *K* is provided. By means of adjustment levers *L* and *M* the automatic governor may be cut out, which

makes it possible to regulate the speed by hand or by means of a remote speed control J, set from the switchboard. The control from the switchboard is also very convenient when it is necessary to set the engine in parallel with the outside current system.

For steam-pressure regulation N_1 and N_2 may be used in the form of ordinary oil-controlled precision steam-pressure governors. (Carl Züblin in *Die Wärme*, vol. 58, no. 10, Mar. 9, 1935, p. 160, 1 fig.)

Sonnleithner Single-Cylinder Reciprocating Steam Engine

IN MANY cases where a steam engine is used the exhaust steam is employed for heating purposes. Many methods are available. There is, for example, the back-pressure steam engine the entire exhaust steam of which can be sent into the heating system, but where it is only seldom that the output of exhaust steam exactly equals the demand for steam for heating, a compound machine may be used with bleeding. Paul Beck, in Munich, has proposed the combination of two steam engines for the same purpose. In his apparatus one of the machines is a back-pressure and the other a condensing steam engine, the two being so connected that the former generates enough steam to correspond to the available fall of pressure in the heating system; the condensing engine produces the rest.

To accomplish this the cut-off of the back-pressure machine is controlled by a pressure governor which permits just enough steam to go into the back-pressure cylinder to maintain the desired uniform pressure in the heating-steam piping. The two machines, the back-pressure and condensing, are coupled to each other and work either on the same crankshaft or on joint transmission shafts. The condensing machine is controlled by an output governor which, because of the coupling of the machines, takes care of the output of both units and gives the condensing machine such a cutoff as will permit it to produce exactly the amount of output lacking.

The two reciprocating engines proposed by Beck are combined into a single-cylinder engine in a patent issued to Sonnleithner (German patent No. 211, 922). In this machine one side of the piston, usually the cover side, operates exclusively under back-pressure conditions, and, as in Beck's system, has a cutoff controlled by a pressure governor. The other side of the cylinder of the same machine operates as a condensing engine and delivers the remainder of the output. Its cutoff is controlled by an output governor of the machine (Fig. 6). The Sonnleithner engine is double acting, but where only very little or very much heating steam is required may run practically like a single-acting machine. This causes the variations of tangential force at the crankpins to be greater than in the

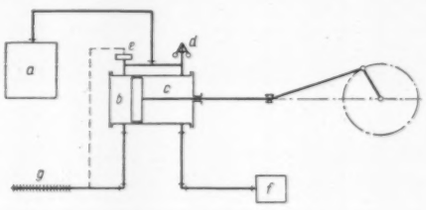


FIG. 6 GENERAL DIAGRAM OF THE SONNLEITHNER SINGLE-CYLINDER STEAM ENGINE (a = boiler; b = back-pressure side; c = condensing side; d = output governor; e = pressure governor; f = condenser; g = heating system.)

case of a conventional single-cylinder steam engine. The Sonnleithner engine requires therefore a heavier flywheel. The Sonnleithner machine strictly speaking consists of two single acting parts. Because of this it is impossible to convey the entire live steam after it has done its work in the engine into the heating system as exhaust steam. This is so because the condensing part must at least receive a minimum of its cutoff, as otherwise it will be running dry. For the same reason when only very little or no heating steam is required, the steam used on the back-pressure side must be exhausted to the atmosphere, because this side of the cylinder must also receive its minimum cutoff. Several units of the Sonnleithner machine have been built and operated. (Dr. of Engg. Kinkeldei in *Die Wärme*, vol. 58, no. 20, May 18, 1935, pp. 313–316, 5 figs.)

VARIA

Examination of Dusts by Polarized Light

THE author describes a process of microscopic examination of silicious dusts carried out with a petrological microscope using polarized light. He also suggests that instead of mounting the dust in Canada balsam, it be mounted in a new artificial resin called hyrax, of which the refractive index is 1.80. Then the appearance in polarized light is the same as when the dust was mounted in Canada balsam, but when the Nicol prisms are withdrawn and the slide viewed by ordinary light, it is apparent that not only are the greater number of the particles not seen in polarized light, but also that many of the needle-shaped particles visible in polarized light are actually edges or lumps of irregularly shaped particles. This is shown in the figure which is the same field of a silicious mine dust mounted in hyrax, magnified 200 times, and photographed first in polarized light and then in ordinary light. Actually by inserting a unit retardation plate of gypsum between the polarizer and analyzer, polarizing effects may be rendered visible with rather smaller silicious particles than 10μ, perhaps down to 2μ or 3μ, but the explanation given of many of the needle-shaped particles applies in this case also. It is not suggested that some fibrous mineral such as sericite is not found in banket, but it is clear that many of the needle-shaped particles which are visible in mine dusts viewed by polarized light between crossed Nicols are the edges or humps of larger particles. The photographs also render it obvious that polarized light is in general unsuitable for the examination of these silicous mine dusts, as an entirely misleading picture of them is obtained. In order to procure satisfactory information, it is necessary to examine them by ordinary transmitted light, using high-power optical arrangements. (H. S. Patterson, *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. 35, no. 10, April, 1935, pp. 300–301)

Training of Machinists in Germany

IN Dusseldorf is the German Institute for National Socialistic Technical Research and Training of Labor commonly known as Dinta.

The Dinta's purpose is to help plants with their questions of apprenticeship. It steps in only when asked to do so. No detail of its work, particularly the number of men put through, is given. The general method of training is as follows: The boys are accepted only after a strict examination, and for the first few months all of the metal-working apprentices learn the fundamentals of their craft at the vise. It is only after that that they start on the machines. One full day of each week is reserved for schoolroom instruction, and this academic work runs through the full four years of apprentice training. After completing two years in the apprentice shop the boys work in the various shops of the company for specific periods. Every plant is being "requested" by the government to augment its apprentice force each year by some 15 to 20 per cent. (K. H. Condit, *American Machinist*, vol. 79, no. 17, Aug. 14, 1935, pp. 577–578, illustrated)

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers, A.S.M.E. Activities

Turbines for Wheeler Dam

AT THE Semi-Annual Meeting of The American Society of Mechanical Engineers, Cincinnati, Ohio, June 17–21, F. H. Rogers and R. E. B. Sharp, of the I. P. Morris Division, Baldwin Southwark Corporation, Philadelphia, Pa., presented a paper under the auspices of the Hydraulic Division entitled, "45,000-Hp Propeller Turbine for Wheeler Dam." The paper was published in the August issue of MECHANICAL ENGINEERING, pages 499–506. At the time of presentation considerable discussion developed, to which there have since been added other comments. These discussions have been submitted to the authors of the paper who have prepared the customary closure. Discussion and closure follow.

BY R. M. RIEGEL[1]

An explanation of certain features of the power development at the Wheeler Dam may be of value in an understanding of the size and governing characteristics of the unit. Back of the purchaser's specifications are certain facts and assumptions, some of which are worthy of elucidation.

Why only one unit? When the construction of Wheeler Dam was authorized by executive order in the summer of 1933, there was under construction a large lock at this point, the work on which was under the direction of the Corps of Engineers and under the appropriations for River and Harbor Improvements. The lock would not be usable until the dam, projected for some years by the Corps of Engineers, should be built. The Tennessee Valley Authority arranged with the Bureau of Reclamation to design the dam and at the same time began power studies to determine the place of this dam in the future power system which might be developed as dams were built in the Tennessee River.

The original intention was to install no generating equipment and to provide only an intake structure for a future power plant. However, it was necessary to determine the essentials of the future station so as adequately to design the intakes, and considerable detail design of the station had to be undertaken. The propeller type of turbine, of the maximum size to be depended upon, was recognized as the appropriate one. This type required a low turbine setting and a deep draft tube, which at Wheeler necessitated heavy rock excavation about fifty feet in depth. To postpone the deep draft-tube excavation until the power house should be constructed below an intake carrying full head was regarded as a hazardous program. It was recognized as highly advantageous to have a manufacturer's design of tube for determining the necessary excavation, and the check of a manufacturer upon the inlet structure would also be valuable.

The power studies in the meantime showed that Wheeler was a favorable site for a peak-load plant, if included in a sufficiently large system, and indicated that an ultimate plant capacity of at least 280,000 kw would ultimately be advantageous, corresponding to eight units of 35,000 kw. The Safe Harbor units were sufficiently large to afford a precedent for wheels of the propeller type.

Moreover, the marginal investment necessary to provide an initial unit might be made profitable. With no power development, revenue would be nil and it would be necessary to import power to operate the lock and spillway gates. With Norris reservoir in operation, the minimum flow at Wheeler would be in excess of the requirement for one unit, and the power from such unit would have the maximum degree of marketability. All these considerations led to the decision to install one unit.

The head range is remarkably small for a river of 30,000 miles of drainage area. The river at Wheeler is 6800 ft wide, and the location is at the head of Wilson pool. The backwater curves for high water are relatively flat and the range of tailwater is only 7 ft, viz., from elevation 505 to elevation 512 for a range in discharge from zero to 650,000 cfs. When a projected increase of 2 ft in the height of gates at Wilson Dam is effected, this range could be brought down to 5 ft.

The normal head water is at elevation 555, but for purposes of mosquito control the annual range will be between elevations 556 and 553. A similar range will be obtained in the Wilson pool. Allowing also for storage draft of 5 ft in the Wheeler pool (66,000 acres at elevation 555) the extreme head range will be from 43 to 52 ft. The more normal range will be from 45 to 50 ft, and 48 ft was fixed as the rated head.

Whether to purchase the first unit of the fixed-blade or the Kaplan type was a disputed question, and alternate bids were asked. The choice of the fixed-blade type was a result of the following reasoning: The plant should ultimately have a combination of the two types to take care of fluctuations of load. The fairly constant head favored the fixed-blade type. With minimum streamflow at about 13,000 cfs after Norris Dam is in operation, there will always be water to waste with one unit in operation, and efficiency therefore had little value initially. No prediction as to load requirements could be made at the time of awarding bids as to the second or subsequent units. The decision was made to purchase the fixed-blade unit and to allow the development of the Authority's program to determine the type of succeeding units.

The horizontal leg of all the eight draft tubes is being constructed now, with part of the elbow for No. 2 unit. The spacing of future units had to be assumed, of course, and the draft tube for No. 1 was in harmony with current design. With the excavation made, as it was, cofferdam construction for the future construction of draft tubes would have been difficult, involving 50 ft of depth of water. The horizontal legs are designed to act as a buttress structure, in which gates or stop logs can be placed, thus eliminating the cofferdam, when the elbows of future draft tubes are constructed.

The Authority is looking forward to other developments on the Tennessee River in which the power plants must closely resemble Wheeler, in head and capacity of units. In all of these, exca-

[1] Tennessee Valley Authority, Knoxville, Tenn.

vation for draft tubes will be an important economic factor. An arrangement has been made with the manufacturer to modify the model described by the authors by varying the bottom slope of the horizontal leg so as to determine the effects of that slope on the efficiency and capacity of the units. These tests will be made upon a model of the Kaplan type so as to observe the effects of varying blade angles. If favorable results are obtained, the designs for future plants will reflect them.

As to the progress of construction, the draft-tube concrete for this unit is being poured and the erection of embedded parts will begin in a short time. The complete unit will probably be placed in operation in the fall of 1936.

BY N. B. HIGGINS[2]

The increase in popularity of the propeller type unit and the increase in physical dimensions during the past decade has been notable. However, at the present time there are relatively few data on prototype efficiency for runners above 200 in. in diameter. Since the Moody formula was developed more than ten years ago from a study of laboratory and corresponding prototype efficiencies, many of the recent propeller-type installations far exceed in size the range of runner diameters covered by the tests upon which the formula was based.

It has been the feeling of some hydraulic engineers for the past several years that the Moody formula gives values of expected efficiency which are too high for these large-diameter runners. Tests made recently substantiate this opinion.

The Moody formula has been used with a high degree of success in the case of Francis turbines but there appears to be some question as to its unreserved application to propeller turbines. After all, it is an empirical means for taking into consideration the effect of the difference in Reynolds' number between the model and the prototype. Unfortunately, it is not possible to test both under the same flow conditions, and the only way of reasoning from one to the other is to gather experience from a large number of cases as has been done in the past with Francis runners. The effect of size is to increase the efficiency for the reason that, in general, there is a reduction in coefficient of friction with increase in Reynolds' number. It may prove that the increase in efficiency observed in past experience is caused mainly by the sudden drop in resistance in passing through a critical range. For propeller turbines the model itself may have a flow pattern that is already beyond a critical range and so no marked gain in efficiency can be expected.

It is not to be expected that for a turbine the plot of friction against Reynolds' number will be as well defined a curve as in the case of a simple geometrical form such as a sphere. Instead of one characteristic dimension upon which to base the Reynolds number, there are many such dimensions and the flow pattern may vary considerably in different parts. The resistance curve, therefore, if we could take a single model and test it over a wide range, would probably be a composite of an infinite number of individual curves, with the net effect that critical regions would be blurred somewhat as shown in Fig. 1. It is obvious that even though some gain in efficiency might be expected in passing from model to prototype, there would not be as great a gain as has actually been experienced with Francis wheels upon which the Moody formula has been based. Experiments at large Reynolds' numbers have indicated that there may be even an increase in friction as suggested by the upward turn of the dotted curve in this figure.

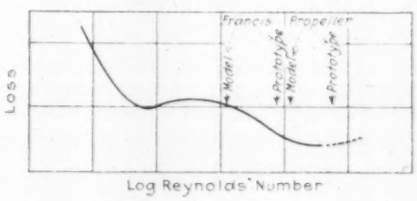


FIG. 1

It is believed that the water passage shown in Fig. 2 of the authors' paper does not present difficulties which would make field tests impossible. It is probable that the intakes are too short for some accepted testing methods, but it would appear that a satisfactory set-up is provided for the two-type current-meter method. Neither the vicinity of the trash racks nor the bell-mouth could be looked upon as obstacles. The influence of similar racks under more adverse conditions at Safe Harbor was properly accounted for by this method, and the bell-mouth effect was found to be particularly beneficial in preventing backflow. It will be a real loss to the industry if such careful model tests as are described are not supplemented by equally complete field tests.

The authors emphasize that the runner selected should operate without pitting at the value of sigma which will exist at the plant. The fact that the runner cavitates only when the sigma is less than the plant sigma does not necessarily

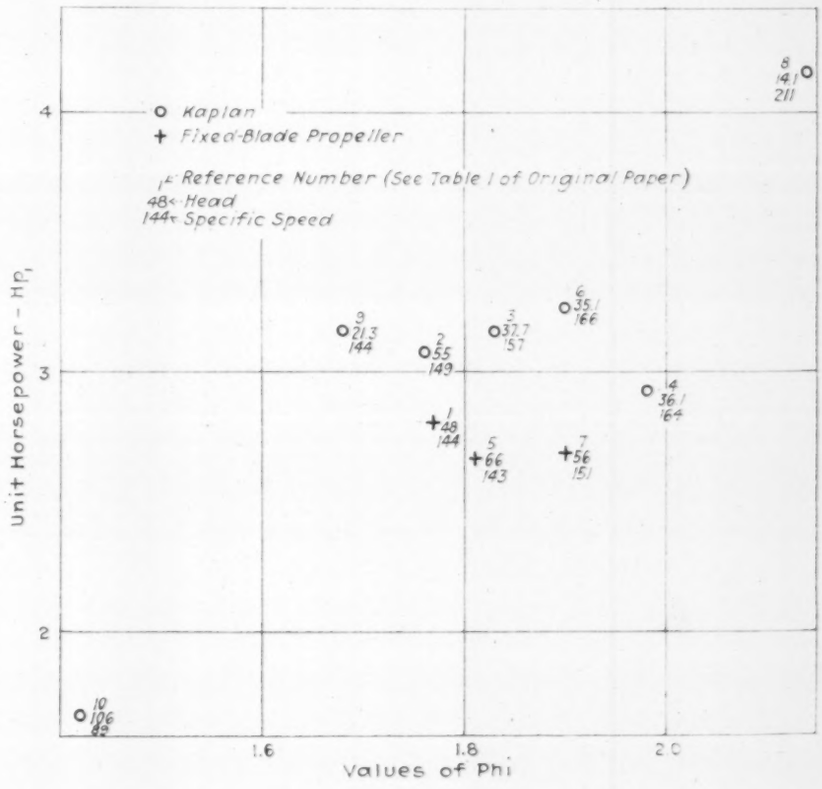


FIG. 2

[2] Chief Engineer, Safe Harbor Water Power Corporation, Baltimore, Md. Mem. A.S.M.E.

mean that there will be no pitting. Assuming a turbine is well designed, there should be no trouble from general cavitation on the suction side of the blades. Of equal importance, however, are various factors which may cause local cavitation and severe pitting. Some of these factors are faulty execution of leading edges of the runner blades, irregularities in blade profiles, unsuitable stay and guide-vane designs, and influence of gap clearances. It is believed that the design of these details is of equal importance in minimizing pitting as is the proper selection of the runners with respect to plant sigma. In this respect, machining of the blades would probably prevent one source of possible local cavitation and consequent pitting. Furthermore, prewelding of certain areas of the blades would retard the progress of pitting that may not otherwise be prevented.

There is great need for careful study of design principles and much experimentation should be done; the field for laboratory work is large if we may judge by the improvements that have been made to large prototypes during the past few years.

From Fig. 6 of the authors' paper it would appear that the scroll case with splitters located in one of the intake bays did not show as high an efficiency as without the splitters. Since the efficiency of the entire intake structures was determined, this result may be misleading. Theoretically, the installation of splitters should be beneficial. That this result was not achieved in the course of the model test may be due to the fact that the splitters may have reduced the discharge of the intake bay in which they were installed, crowding the water into the other two intake bays. This crowding effect may be detrimental to the efficiency of the other two bays and the part of the scroll case downstream of them, and may offset the gain derived from the splitters in the first bay.

The comparisons with other turbines of great size given in the authors' Table 1 are interesting, but further comparison may be made on the basis of phi and unit power, that is, the horsepower of a wheel of 1 ft diameter and operating under a head of 1 ft. This is shown in Fig. 2 which shows that for the two cases which are designed to meet unusual conditions, i.e., the exceptionally high-head plant on the Shannon, and the very low-head plant at Vargoen, there is a definite relation between phi and unit power. In the case of Shannon, the adoption of a Kaplan unit for this head is possible only with considerable sacrifice in unit capacity which accompanies a low value of phi. In the case of Vargoen the low head permits a high phi without dangerous cavitation, and this in turn results in a high unit capacity.

If we consider further the way the Kaplan points stand with respect to those of fixed-blade propeller units, it will be clearly seen that there is in general a sacrifice in unit capacity by the adoption of the fixed-blade propeller. In comparison with the other two fixed-blade units the Wheeler unit is an advance, but in spite of this there is a sacrifice in unit capacity of about 10 per cent.

If the conditions of operation are such that there will be adequate river flow for continuous operation of the first unit at maximum output, there is obviously a loss in capacity through the adoption of the fixed-blade unit, and it would be interesting to know how the factors such as price differential and maintenance have been weighed in making this selection.

Rubber bearings have been installed on certain of the hydraulic turbine units in the hydro plant at Holtwood, Pa., to replace the original lignum-vitae bearings and have given satisfactory performance for more than eleven years. Lignum-vitae bearings required replacements approximately every three years.

In view of the generally satisfactory performance of these rubber bearings, serious consideration was given to the use of this design on the large units now in operation at Safe Harbor. The Safe Harbor units, however, differ from the Holtwood units and also from the unit to be installed at Wheeler dam, in that they are equipped with only two guide bearings, the upper one below the generator rotor and the lower one at the turbine head cover. It was feared that in view of the resilience of the rubber material excessive oscillation might occur, which might produce an unsatisfactory condition at the generator rotor which overhangs the upper bearing. In view of these possibilities oil-lubricated babbitt-lined bearings were selected, as the babbitt metal should serve as a more rigid guide than rubber.

The use of a larger number of turbine guide vanes or gates should tend to reduce the radial depth of each gate and consequently the overhang of the discharge end with respect to the throat ring, appears to be advantageous. With the overhang practically eliminated, it is probable that smoother flow will occur at the entrance to the throat ring, and this condition should lessen the possibility of cavitation at that location.

BY S. LOGAN KERR[3]

One feature of the paper by Rogers and Sharp which has provoked discussion is that of conducting guarantee tests on a model unit in the manufacturer's laboratory to establish whether the unit had met the requirements of the contract in so far as efficiency is concerned. It is well to consider carefully all of the factors that enter into a decision of this nature. The writer will therefore endeavor to outline some of the more important phases of the problem.

The accuracy of field testing on large units, in which water passages are arranged in such a manner that the Allen or Gibson method can be applied readily, should give the true efficiency within about one half of one per cent of the correct value, if calibrated electrical instruments are employed and if the test is conducted by experienced and skilled persons.

If the conditions for such tests are not ideal this variation may reach one or two per cent, or even more in extreme cases.

In the case of the Wheeler unit the water passages are extremely short, the velocities are low, and the quantity of water to be measured is on the order of 9000 cfs. The application, therefore, of either of the accepted American methods, namely, the Allen or Gibson methods, is out of the question. The possibility of using current meters for the flow measurement was considered carefully and the experience in applying current-meter testing to three major hydroelectric stations in the United States and Canada was given a great deal of weight. In none of these three installations was either the manufacturer or the purchaser fully satisfied in regard to the accuracy of the test and in some cases the tests were repeated many times over a period of several years before reasonable agreement could be secured.

In negotiations with the Tennessee Valley Authority and other agencies of the Federal Government, it was felt that the results of any field tests in this particular installation would be open to considerable difference of opinion, and hence a decision was reached to eliminate the field testing for efficiency and to check only the power guarantee under field-operating conditions.

In order to establish to the satisfaction of the Government the contractor's compliance with the guarantee clauses,

[3] Senior Mechanical Engineer, Passamaquoddy Project, U. S. Engineer Office, Eastport, Maine; formerly, Research and Test Engineer, I. P. Morris Division, Baldwin-Southwark Corporation, Philadelphia, Pa. Mem. A.S.M.E.

it was agreed that a truly homologous model would be constructed and tested in the manufacturer's laboratory after a careful calibration of all the measuring apparatus which were to be utilized on the test.

Investigation showed that the laboratory testing of hydraulic turbine models had been used as a basis for the fulfillment of contractural obligations since the earliest days in the Holyoke testing flume or in the flumes at Lowell, Mass.

Some of the earliest water wheels purchased for commercial installations were tested in these two flumes and a bonus or penalty provided in the contract based upon the results of these tests. As the size of units increased, the capacity of these flumes was exceeded and other methods employed to establish the performance of main units.

Improvements in design were found to result from continuous research and testing work and this led the manufacturers to establish their own laboratories. In 1918 the I. P. Morris Company constructed its first permanent laboratory. Since that time all other manufacturers have established one or more experimental laboratories, and several universities and technical schools also constructed large-scale model turbine-testing laboratories which are occasionally made available to other investigators.

TABLE 1

Installation	Runner diam. in.	Model diam. in.	Maximum model efficiency, per cent	Model efficiency at design phi, per cent	Efficiency increment, per cent	Expected maximum efficiency, per cent	Field test, per cent	Differences, test vs formula, per cent	Method of water measurement,
Queenston, No. 5	112.5	36	91.0	91.0	2.3	93.3	93.3	0.0	Gibson
Queenston, No. 7	113.1	36	90.9	90.8	2.4	93.2	93.8	+0.6	Gibson
Niagara No. 19	164.0	36	90.9	90.7	3.0	93.7	93.8	+0.1	Gibson
Spruce Falls	93.0	16	85.7	85.4	5.1	90.5	90.5	0.0	Allen
Anson	92.0	16	86.7	86.0	4.7	90.7	90.5	−0.2	Allen
Holtwood No. 10	149.5	16	87.0	87.0	5.5	92.5	92.8	+0.3	Allen
Cheat Haven	121.0	16	86.5	86.5	5.5	92.0	92.5	+0.5	Gibson
Rumfort Falls	85.0	32	90.2	90.1	2.1	92.2	92.8	+0.6	Allen
Norwood No. 3	170.5	16	87.5	87.5	5.5	93.0	92.5	−0.5	Gibson
Norwood No. 2	173.0	16	88.0	87.4	5.4	92.8	93.0	+0.2	Gibson
West Buxton	133.0	16	85.0	84.8	6.2	91.0	92.1	+1.1	Allen
Upper Tallassee	175.0	16	87.5	87.5	5.6	93.1	92.5	−0.6	Allen
Morony	173.0	16	88.0	87.4	5.4	92.8	93.0	+0.2	Gibson
Chelsea	154.0	16	88.0	87.8	5.2	93.0	92.3	−0.7	Gibson
Light House Hill	84.0	16	88.0	87.8	4.1	91.9	91.5	−0.4	Gibson
Paugan	134.0	16	88.4	88.4	4.8	93.2	92.5	−0.7	Gibson
Dolby No. 8	86.8	16	88.8	88.2	3.9	92.1	93.5	+1.4	Allen
Ghost Development	106.0	16	88.0	87.4	4.6	92.0	92.5	+0.5	Gibson

LABORATORY ACCURACY

The accuracy of laboratory testing is a direct function of the accuracy of the individual measurements of power, head, and quantity. The use of electric dynamometers immediately eliminated many of the errors resulting from water brakes or other power-measuring apparatus, and accurate measurement of total revolutions in a given period of time eliminated the errors of tachometers and other similar instruments. Head measurements can be checked readily and do not give rise to any significant error.

The present source of most discrepancies in laboratory testing rests with the measurement of quantity and not with the measurement of power or head. These differences result from two main factors: (1) Differences in the weir formula employed and variations in the weir design from the types of weirs upon which the original formulas were based; and (2) improper flow in the channel of approach. At present most of the weirs are of the suppressed type and the Rehbock formula is used frequently and calibrations indicate that it is probably the most satisfactory formula to use. Adequate stilling apparatus in the approach channel is essential to establish and maintain the accuracy of weir readings.

When all of these factors had been considered it was felt that the laboratory results would be as accurate as field-test results under reasonably good conditions. By careful testing and calibration, a variation of one-half of one per cent above or below the true results would probably cover the errors in laboratory efficiency.

LABORATORY VS. FIELD PERFORMANCE

In relating laboratory performance with field performance for research purposes it was found that an appreciable increase in efficiency took place in the main unit as compared with the model unit. This increase in efficiency was greater in the larger units than it was in the smaller units and many studies were made to establish the correct amount of improvement which could be expected between the small model turbine and the completed installation in the field.

The usual laboratory-practice measures the power output of the unit, the total quantity and the difference between the head-water and tail-water elevations, commonly called the "gross head," and it is upon this basis that the efficiency is established.

In the main units, the design of the intake structure and the area of the draft-tube outlet are usually fixed by the customer and are not within the direct control of the manufacturer. The practice has been established for many years of basing the efficiency guarantees on the main unit upon net effective head, measuring the pressure head at the entrance to the casing, adding the velocity head at this point and crediting to the turbine performance the velocity head at the exit from the draft tube.

With these two differing standards in mind and neglecting the effect of size, it may be seen that the efficiency of the model unit on a gross-head basis is proportionately lower than the efficiency of the main turbine on a net-head basis since the intake and exit losses are charged against the laboratory turbine but are deducted from the head acting upon the main unit.

STEP-UP FORMULA

The Moody formula was developed primarily to relate established laboratory practice with field performance so that the performance of the unit could be predicted with reasonable accuracy if a model turbine was tested in the laboratory. A great many installations were selected upon which accurate laboratory tests and field tests were available and an exponential formula was established for the reduction of loss in proportion to diameter of units. The exponent of 0.25 was selected as giving the closest agreement between the laboratory and field performance in relation to diameter and has been used for many years in the prediction of main unit performance, for the purpose of making proposed efficiency curves, and for establishing permissible guarantees on many different types of water wheels.

As a check on the accuracy of the Moody formula in predicting field results from laboratory tests of models, a group of installations, eighteen in number, were studied. Table 1 of this discussion identifies the installation, gives the main-unit diameter as well as the model diameter, the laboratory efficiency at the cor-

rect value of phi, and the main-unit performance as compared with the stepped-up value of the model tests. In each case the model-runner test efficiency at the best condition has been used to establish an efficiency differential to be added through the operating range. Thus, a model unit showing a maximum efficiency of 87 per cent might have a differential of 6 per cent to be added if the main unit was to be of appreciable size. If the exact operating conditions did not correspond to the best efficiency on the model but came at some point where the efficiency of the model was about 86 per cent, then the main-unit efficiency would be expected at approximately 92 per cent as compared with 93 per cent if operated at its best conditions. These corrections have all been considered in the preparation of Table 1.

It will be noted that in 12 cases the field-test efficiency equals or exceeds the model test stepped up to the main-unit size, while in six cases the field test shows slightly lower than the stepped-up value.

If a band of efficiency one per cent above and one per cent below the stepped-up values were drawn, 17 out of the 18 cases would fall within this band.

If the performance of the model units is within one-half of one per cent in the laboratory and the performance of the main units is within one-half of one per cent in the field then the total spread of one per cent above or below the stepped-up values would indicate that the Moody formula, applied as described in this discussion, was definitely proved to be a reliable basis for predicting field performance.

VARIATION BETWEEN LABORATORIES

In using this formula generally it is necessary to consider the differences in efficiency existing in different laboratories. Under the writer's direction, tests have been made on the same model unit in different laboratories with variations as great as two per cent in their maximum efficiency, the lower efficiency in most cases being that obtained in the I. P. Morris Laboratory. It is felt that these variations are principally the result of differences in weir measurement and in some slight degree, to differences in power measurement.

It would be highly desirable to have all manufacturers' laboratories calibrated on the same basis so that the results in one laboratory could be compared directly with the results in any other laboratory. The same standard model unit could be installed successively in each laboratory and tested through its entire range of operation. The various laboratories could thus be calibrated and minor changes made in the measuring devices until the performance of this standard unit was identical. If agreement could not be secured, it might be possible to establish a correction factor to be applied to individual laboratories in order to make their results directly comparable.

The difficulties and expense attendant upon field tests of large low-head units will doubtless stimulate the desire of many purchasers to utilize accurate laboratory tests of directly homologous model units to determine the fulfillment of efficiency-guarantee clauses rather than to spend large sums of money for field tests under conditions where reasonable accuracy would be questionable.

BY LEWIS F. MOODY[4]

The following discussion is directed to only one of the factors discussed in this comprehensive paper, namely, the subject of the relation of the field efficiency of a large turbine unit to the efficiency of a homologous model. This discussion is not offered by way of criticism since the writer is in agreement with the statements in the paper, but is presented for the purpose of outlining briefly the conception on which the formula was based, and to record a re-analysis of the problem utilizing the recent rational theory of conduit friction developed by Th. von Kármán and L. Prandtl, which is found to give results in good agreement with the original formula.

Neglecting the separate consideration of the losses in a hydraulic turbine due to leakage and mechanical friction, and not attempting to separate the eddy, enlargement, or residual velocity-head losses from the surface friction, but treating all losses "in bulk" and assuming them to vary in the same manner as pipe friction, we can apply the so-called Darcy formula and express the ratio of loss of head to the net effective head on the turbine as $\frac{h_L}{H} = 1 - e = f\frac{L}{d}\frac{V^2}{2gH}$, in which e is the turbine efficiency, L an equivalent length of water passage, d an effective diameter of an equivalent pipe, f a variable coefficient which is a function of the Reynolds number and of the relative roughness of the surfaces ϵ/d.

In two homologous turbines operating under dynamically similar conditions

$$\frac{1 - e_1}{1 - e} = \frac{f_1\frac{L_1}{d_1}\frac{V_1^2}{2gH_1}}{f\frac{L}{d}\frac{V^2}{2gH}}$$

and from their geometric similarity $L_1/d_1 = L/d$ and for dynamic similarity $V_1^2/2gH_1 = V^2/2gH$ so that $(1 - e_1)/(1 - e) = f_1/f$.

The first formula developed for evaluating this ratio was that of Camerer, based on the unsatisfactory Biel formula for f.

The writer, believing that the degree of approximation involved in the available figures for turbine efficiencies, due to the wide range of possible error in measurement of water and other factors and the frequent variation from exact geometrical similarity, would hardly justify an attempt at any elaborate formulation, proposed the use of the simple exponential form of expression[5] for f. It was considered that turbines, including the usual sizes of models used, lay in the region of high Reynolds' numbers, where viscous forces are practically negligible, so that f becomes a function only of the relative roughness. Accordingly, a pipe-friction formula was adopted of the type

$$h_L = \text{const.}\ \frac{L}{d^{1-n}}\frac{V^2}{2g}$$

or $f = \text{const.}/d^n$

giving $\frac{1 - e_1}{1 - e} = \left(\frac{d}{d_1}\right)^n = \left(\frac{D}{D_1}\right)^n$

in which D and D_1 are any corresponding diameters, such as throat diameters; and from pipe-friction data and considering the partial effect of losses other than friction it was estimated that n should have a value close to $1/4$, which gave the simple relation

$$(1 - e_1)/(1 - e) = (D/D_1)^{1/4}$$

Determining n from all available field and model tests of homologous turbines gave the same mean value, and showed that the formula agreed satisfactorily with existing efficiency data and was well adapted for practical use.[6]

The writer has been curious to see whether the functional relationship of the friction factor to size of conduit re-

---

[4] Professor of Hydraulic Engineering, Princeton University, Princeton, N. J. Consulting Engineer, Baldwin-Southwark Corporation. Mem. A.S.M.E.

[5] "The Propeller-Type Turbine," by Lewis F. Moody, Trans. A.S.C.E., vol. 89 (1926), pp. 625–647.

[6] Shortly after the formula was proposed, Staufer published a similar formula and arrived at the same exponent. "Einflüsse auf den Wirkungsgrad von Wasserturbinen," by Franz Staufer, *Z.V.D.I.*, vol. 69, no. 13, Mar. 28, 1925, pp. 415–417.

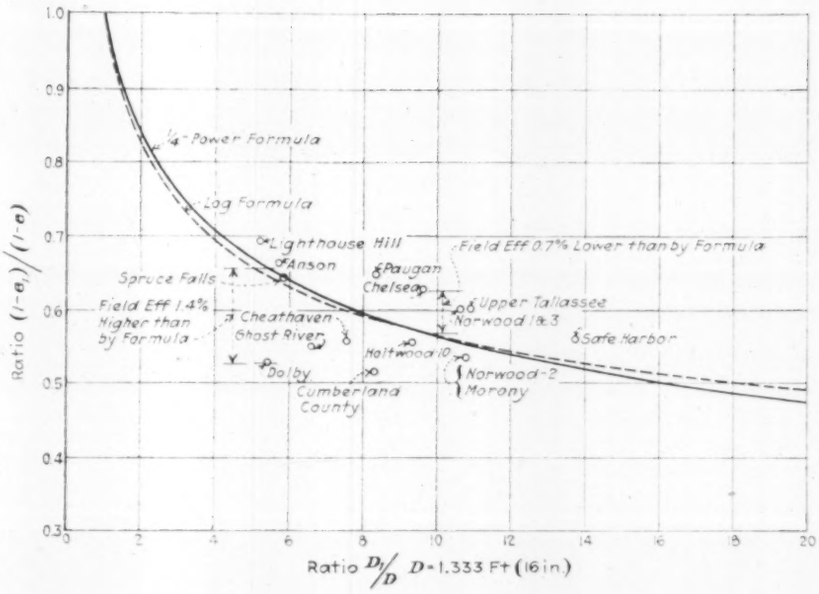


FIG. 3 COMPARISON OF RESULTS OF THE MOODY 1/4-POWER FORMULA, THE LOGARITHMIC FORMULA, AND ACTUAL TESTS

(The Safe Harbor point corresponds to data presented by Rogers and Sharp in the closure to this discussion. The remaining points are from Table 1 of Mr. Kerr's discussion. Note that the Dolby point, showing the greatest discrepancy, is from tests in which the spreading draft tubes were not completely homologous, the model tube having restricted dimensions and a low central cone, while the field unit has a high cone and more liberal dimensions.)

sulting from the new rational theory of pipe friction of von Kármán and Prandtl would result in an entirely different mode of variation of efficiency. Accordingly, the Kármán-Prandtl equation for rough conduits (high Reynolds' numbers) was applied[7]

$$f = 1/(2.0 \log r/\epsilon + 1.74)^2$$

which may be written $f = 1/(2 \log d/\epsilon + 1.14)^2$; or calling $1.14 = 2 \log a$

$$f = 1/(2 \log ad/\epsilon)$$

If the effective mean diameter corresponding to the water passages d is some fraction m of the turbine throat diameter, or $d = mD$

$$f = 1/(2 \log amD/\epsilon)^2$$

With a, m, and ϵ the same in both large unit and model, $am/\epsilon = C$, a constant, so that $f = 1/(2 \log CD)^2$ and

$$\frac{1 - e_1}{1 - e} = \frac{f_1}{f} = \left(\frac{2 \log CD}{2 \log CD_1}\right)^2$$

or

$$\frac{1 - e_1}{1 - e} = \left(\frac{\log CD}{\log CD_1}\right)^2$$

Here common logarithms are to be used. To compare this formula with the previous 1/4-power formula, a curve was plotted for a constant model size of 16 in. or $1\frac{1}{3}$ ft throat diameter and large units ranging up to 20 times the model size, or 26.67 ft throat diameter. The figure shows a comparison of the results by the two formulas. The value of C was taken as 800, so that the two formulas agree in the region where the most reliable data are available and where the 1/4-power formula is best supported. A number of field tests for which accurate homologous model tests are available are show on the same illustration, Fig. 3, from data compiled by S. Logan Kerr.

It will be noted that within the range shown, which covers the field of present practice, the two formulas agree within a variation of less than one-quarter of one per cent in efficiency, based on 87 to 88 per cent model efficiency. The variation is believed insignificant and of no practical importance in view of the wide spread to be expected in field measurements. Although the two functional relationships appear totally unlike, the original 1/4-power formula gives a curve almost identical with the new one, and is evidently a close and satisfactory approximation.

[7] "Neuere Ergebnisse der Turbulenzforschung," by L. Prandtl, *Z.V.D.I.*, vol. 77, no. 5, Feb. 4, 1933, pp. 105–114, Eq. [16].

"Some Aspects of the Turbulence Problem," by Th. von Kármán, MECHANICAL ENGINEERING, July, 1935, pp. 407–412.

"On Velocity Formulas for Open Channels and Pipes," by Erik Lindquist, World Power Conference Sectional Meeting, Scandinavia, 1933, Transactions, vol. 1, pp. 177–234.

AUTHOR'S CLOSURE

The authors appreciate the discussions submitted by N. B. Higgins, S. Logan Kerr, and L. F. Moody. Mr. Kerr's and Mr. Moody's discussions deal primarily with the testing of model units and the prediction from these model tests of field performance by the use of the Moody formula. As both of these discussions amplify points made in the original paper they need no further discussion from the authors.

With regard to the discussion submitted by Mr. Higgins, the authors desire to make the following reply:

It is true that the runner diameters of recent turbine installations are increasingly great, particularly those of the propeller type. This fact, however, is not a sound basis for the statement that the Moody formula does not hold for these larger diameters in the absence of conclusive test data for such larger sizes. As is brought out in Mr. Kerr's discussion, the Moody formula is closely applicable for the largest Francis runners with a diameter of 173 in. The presentation of actual test data for larger size propeller runners than are included in our Table 2 will be of definite value.

The authors do not hold with Mr. Higgins' conception that the increase in efficiency of the prototype over the model is due to increase in Reynolds' number. In our view this increase is independent of the velocity and is due entirely to a reduction of the relative roughness of the surfaces corresponding to the increase in size of water passages. Certainly the efficiency of the prototype will be higher than that of a small model even with the same Reynolds' number in both cases, on the basis, of course, that the value of Reynolds' number for both instances is far beyond the critical velocity, and in the region of completely turbulent flow.

We are unable to understand the basis for Mr. Higgins' Fig. 1. Even aside from the question of variation of efficiency with the Reynolds number, it would be of interest to know the basis for the relative location of the Francis and propeller model and prototype lines on this diagram; also what basis is there, aside from the general statement, made for the irregular shape of this curve and specifically for the upward-turning dotted portion. In short, the theory brought out in Mr. Higgins' discussion as to the relative efficiency step up of Francis vs. propeller runners is of interest as such, but unfortunately, he presents no data to show that propeller-type runners do not have an efficiency step up in general agreement with the Moody formula.

The step up in efficiency from the Safe Harbor model efficiency to the field-test efficiency is based on net head, as determined by the Gibson method of 6.0 per cent, whereas the step up by the Moody formula is 6.54 per cent, with resulting discrepancy of 0.54 per cent. This small variation, which is well in line with that found for smaller units, does not point toward the inaccuracy of the Moody formula, as applied to large propeller installations.

After a very careful study of the size and proportions of the water passages at the Wheeler plant, as well as the quantity of water to be measured, it was concluded jointly by the TVA engineers and all the turbine manufacturers who were bidding, that great difficulties would be experienced in making field tests and that the accuracy of such tests by any method would be very doubtful. Many difficulties experienced with the two-type current-meter method at the Safe Harbor plant did not seem to warrant dependence on this method in its present state of development for the acceptance tests. It was felt that the chances for material departure from the truth by such a field test are decidedly greater than from an incorrect step up due to the Moody formula.

Local cavitation and pitting will undoubtedly occur if there are material irregularities in the blade contour, or if the inlet edges are not properly formed. Great care is taken to prevent these conditions during manufacture. Machining of the blades is undoubtedly of some advantage, although costly, and it is believed that careful finishing and grinding to template will give faithful reproduction.

Tests definitely show that cavitation reduces the runaway speed to a greater extent in a fixed-blade than on a Kaplan-type turbine. The tests, however, were not conclusive as to the exact amount of reduction.

The smaller hub diameter of the fixed-blade propeller runner results in a greater number of blades and gives superior performance due, apparently, to the portion of the runner near the hub acting as a runner of low specific speed with consequent need for ample guidance and, therefore, greater number of blades. The aggregate blade area is about 390 sq ft.

It is difficult to see how, as has been suggested, if the casing splitters reduce the flow in their bay, they can be beneficial even for that portion of the casing. Reduced flow generally means increased loss. After all, the important consideration is the overall result, and that was not improved by the splitters.

Bids were asked for and received on both types. The TVA decided on the type adopted, and their reasons therefore are outside the scope of this paper. There is naturally with the Kaplan type a greater unit power at the rated output than with the fixed-blade type, due to blade adjustment beyond the best efficiency point.

At the Holtwood plant, the first experience data relative to the life and reliability of rubber bearings applied to hydraulic turbines were obtained.

The rubber bearing was recommended for the Wheeler turbine in view of its excellent performance in a large number of plants including two bearing units with overhung generator bearings as described by Mr. Higgins. No unsatisfactory performance due to the resilience of the rubber has as yet been experienced.

The vertical-groove type of bearing gives superior lubrication as compared to the spiral-groove type, in that the distance across the rubber strips in the direction of rotation is less.

A further advantage of the former type is less chance of shutting off the flow due to clogging with foreign material because of the larger number and shorter length of the water passages between the grooves.

The ports at each end of each servomotor are 5 in. in diameter. We consider 12 to 15 fps in this piping as satisfactory.

Cost of Noise

TO THE EDITOR:

In an editorial in the September issue entitled, "Engineers' Interest in Noise," there is one sentence that reads, "People must be willing to pay the price of a noiseless city. . . ."

I wonder if it is thoroughly understood that what people are doing now is really paying for the noise without having the benefit of the quiet. Data exist that show the cost of noise in offices, and an attempt to compile data regarding the cost in factories is under way.

The principal reason that, up to a few years ago, very little information has been available regarding the real cost of noise in offices is because office employees were not on a piecework basis and therefore it was impossible to measure a definite and actual increase in efficiency. Although many thousands of installations of quieting treatment had been made in offices, with satisfactory results, it remained for the Aetna Life Insurance Company, of Hartford, Connecticut, to make what is believed to be the first actual test on piecework employees under the noisy conditions, and to compare the results after acoustical treatment in these same departments.

In *The Bankers Service Bulletin* for June, 1931, P. B. Griswold, assistant secretary of the Aetna Life Insurance Company, gave a summary of the results that had been obtained through the use of quieting treatment. The article showed that the noise level in the room was reduced 14.5 per cent, the efficiency of employees was increased 8.8 per cent, errors of typists were reduced 29 per cent and of machine operators 52 per cent. Employee turnover was decreased 47 per cent, and absences 37.5 per cent. Salary costs were reduced because of the fewer employees required.

So it would seem that quieting treatment in this office certainly paid for itself. Therefore it is not necessary that "people must be willing to pay the price of a noiseless city," because they are already paying it now and receiving nothing for their money, although they do not realize it.

There is a vast field open for this type of research in factories. It is, of course, evident that in certain factories the noise level would be so high that acoustical treatment would not reduce it to a satisfactory point, but in many factories it would give amazing results. It is hoped that in the course of the next year some figures showing actual results under quiet conditions as compared with the same operations and same employees under noisy conditions will be available.

F. E. BERRY, JR.[8]

Classification of Lubricants

TO THE EDITOR:

The conclusions found by Virgil M. Palmer and Horace C. Smith in their article[9] about the lubrication program developed by the Eastman Kodak Company are interesting and true.

The writer has done considerable work in specifying lubricants to be used on machinery in the excavating field. It is quite simple to obtain recommendations from one oil company and specify this company's oils. The information from one oil company, however, is not sufficient and the task of specifying the oils of equal quality from all the different oil companies or from the oils available in different sections of the country or foreign countries, is an almost insur-

[8] President, F. E. Berry, Jr., & Co., Inc., Boston, Mass. Mem. A.S.M.E.

[9] "A Lubrication Problem," by Virgil M. Palmer and Horace F. Smith, MECHANICAL ENGINEERING, September, 1935, pp. 565–570.

mountable problem. Each company has its own names for its numerous grades of oil and many of the engineers or salesmen of oil companies can not select an equivalent oil from names alone. Hence it is up to the designing engineer to make extensive tabulations for the many lubricating oils of many companies.

There are at least one thousand names of lubricants, mostly meaningless in themselves. The number of these names could easily be reduced to twenty-five to cover the whole field of lubrication, each name giving the use of the oil in general. The many oil companies could still preserve the individuality of their products. The individuality and qualities would be better emphasized than with the now meaningless names and it would be easier for the user to remember the company which, by his experience, furnished the best quality of a certain name than to remember the specific name under which the oil is sold.

Why not classify oils under principal names like watch oil, sewing-machine oil, bearing oil, engine oil, gear lubricant, and greases, each with a few descriptive variations indicating one of the main standard measurements of oil quality, such as viscosity, oiliness, pouring quality, or adhesion. It would then be easy to prepare lubrication tables and instructions and it would lighten the task of the engineers specifying lubricants because selection would be a more intelligent process than at present.

The lubricant specified could then be obtained throughout the country without translating equal grades into many different names.

WERNER LEHMAN.[10]

Socialization of Housing

TO THE EDITOR:

The promotion of commodious, beautiful, and sanitary homes enlists the idealism as well as the creative instincts of the engineer. However, E. S. Burdell, in his review[11] of the book "Modern Housing," by Catherine Bauer, apparently subscribes to her statement, "The right to live in a decent dwelling has taken its place among the 'national minima'—the right to good and abundant water, to sanitation, to adequate fire and police protection, to the use of paved and lighted roads, and to education." He adds, "it therefore should not be too great a stretch of his [the engineer's] imagination to understand why housing must be added eventually to the list," suggesting a subsidy, and quotes with approval the statement, "This reform [housing reform] failed primarily because all the building projects must pay for themselves." Is it not, therefore, time to ask for answers to certain questions, such as:

Why should the competent and provident be burdened to assist the multiplication of the incompetent and improvident?

Should not each component of the population pull its own weight?

When the sum of the minimum "rights" demanded by politicians for the benefit of various and several segregated classes of voters exceeds the total national output of goods, how are the "minima" to be provided?

Would it not be better, as well as more equitable, if each and all were to offer in a free market the services and goods which they can produce in exchange for those services and goods (such as nicer houses to live in) which they want or desire?

This would not, of course, rule out legalized minimum standards of construction, but it would avoid the diversion of tax-payer's money (and everyone pays taxes ultimately) to provide modernized housing at less than cost to those who are adept in the methods of political favoritism, of which recent "slum clearance" projects now supply ample evidence.

GEO. H. GIBSON.[12]

[10] Chief Engineer, Bucyrus-Erie Company, South Milwaukee, Wis.

[11] MECHANICAL ENGINEERING, October, 1935, pp. 647-649.

[12] Geo. H. Gibson Co., New York, N. Y. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following are records of the interpretations of this Committee formulated at the meeting of September 13, 1935, and approved by the Council.

CASE NO. 808

(In the hands of the Committee)

CASE NO. 809

(*Interpretation of Par. P-216*)

Inquiry: The statement in Par. P-216 would appear to include the segment above or below the tubes but Fig. P-20 does not so indicate. May those provisions be applied to the segment above the tubes?

Reply: The provisions of Par. P-216 may be applied to the segment above or below the tubes, which would permit the omission of staying if the distance from the tangent to the upper side of the top row of tubes, or from the bottom side of the lower row of tubes, to the shell does not exceed $1\frac{1}{2}$ *p*.

CASES NOS. 692, 755, 761, 763, 767, 770, 772, 773, 777, 784, 788, 789, 790, 794, 799, 801, 803. (ANNULLED)

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

The Sociology of Invention

THE SOCIOLOGY OF INVENTION. By S. C. Gilfillan. Follett Publishing Company, Chicago, 1935. Cloth, 5½ × 8 in., 190 pp., graphs, bibliographies, $2.

INVENTING THE SHIP. By S. C. Gilfillan. Follett Publishing Company, Chicago, 1935. Cloth, 5½ × 8 in., 294 pp., illustrations, bibliographies, $2.50.

REVIEWED BY I. N. LIPHSHITZ[1]

IN SPITE of the increasing amount of material written on the history of technology and the subject of invention, there has been little done to examine the socially causative factors in these fields. In the usual discussions, invention is regarded as something apart from the general order of things. There is all too much talk of the inventor and the *different* world in which he lives, the unconscious, chance, and accident in invention. We find a repetition of the popular stories generally known, an effort to "romancify" the inventor and his world, to show him as a different person. And in trying to present the inventor as an object for awe and wonderment, most writers entirely disregard the social roots of the inventive process, the demands of society on the inventor, the interrelation of the inventor and society.

Several writers, among them Waldemar Kaempffert, William F. Ogburn, and Joseph Rossman, have tried to shed light on this subject, and now Dr. Gilfillan comes forward with an important contribution. His "Sociology of Invention" is an excellent study of the social causes of invention and some of its social effects. Its companion volume, "Inventing the Ship," is a discussion of the history of the merchant ship from the point of view of invention. The historical evidence in this volume is used as the basis of the generalizations of the first one, and serves as a case study in inventive development.

Dr. Gilfillan is well equipped to handle the subject. A former university instructor in the social sciences, as well as curator of ships and of social sciences in the Chicago Museum of Science and Industry, he has spent much time in gathering and analyzing his material. The 38 social principles of invention which he presents and develops in these volumes are a masterpiece of concise presentation.

Dr. Gilfillan upholds the cumulative or evolutionary concept of invention. He notes how all invention is dependent upon the prior state of the industrial and societal arts, and how it grows out of them. He examines the social changes causing invention, and the influence of invention upon social change. Though he recognizes the importance of the individual in the development of technology, he states, quite correctly this reviewer believes, that "there is no indication that any individual's genius has been necessary to any invention that has had any importance. To the historian and social scientist the progress of invention appears *impersonal*." We need only remember the oft-occurring phenomenon of duplicate inventions to agree with the principle of inevitability of invention which the author develops.

The work contains an analysis of the long and difficult period usually necessary for inventions to achieve practical importance. The favorable influence upon invention of rapid expansion of population, industry, and commerce is presented. In discussing the factors fostering, retarding, and locating invention, the author examines the trends in specialization of regions, firms, and individual engineers and inventors, and notes their effect in enhancing inventive development.

Though he perceives and discusses the change in the process of invention due to the scientific and organizational nature of modern technology, he does not sufficiently present invention as a branch of engineering, a necessary function of modern industry. He still clings to the concept of the "outsider," one unconnected with the field in which his work belongs, in making revolutionary inventions; though he correctly states that "the far greater and more valuable mass of perfecting inventions are made by insiders." As this reviewer and others have shown on many occasions, there is an ever-decreasing function of the "outsider" or "garret" inventor in a socio-technical system which requires coordinated, systematic, and planned invention.

Dr. Gilfillan maintains that standardization, the growth of capital, and the use of durable materials contain anti-inventive elements, since new developments would require discarding expensive equipment or difficultly established standards. This phenomenon has been noted by many, both social scientists and engineers. We might state though, and I believe Dr. Gilfillan will agree with us, that these factors, though they are signs of a high stage of technical development—a technical maturity—do not preclude further technical advance. Social forces, social lags, influence the trend of technical progress, and it is to these factors that we must look for an explanation and prediction of further developments. The question as to whether technical invention causes social change or social change causes technical invention is a rather difficult one. There is no hard and fast relationship, but rather a constant interaction, at one time invention being the prime factor, at others social elements being the causative factors.

An extremely interesting section of the book, and one which caused considerable discussion when it was published in periodical form, is the chapter in which Dr. Gilfillan notes and discusses the decline in the patenting rate. We would expect a constantly increasing number of patents to be issued with the advance of industry. Yet Dr. Gilfillan has found by a statistical study that "since about 1885 American patents have been increasing only in proportion to the population, no faster, despite all the incitements from increasing industrialism and civilization." Previously there had been a more rapid rate.

What can account for this trend? Dr. Gilfillan presents eleven possible explanations. He divides them into two groups, those which do, and those which do not presume a decline in inventiveness. In the first group he includes standardization, growth of fixed capital, decline of the native ability of the American people, and an indisposition to *fundamental* invention on the part of

[1] New York City. Jun. A.S.M.E.

engineers and trained specialists. These last two reasons, this reviewer would discount as downright nonsense.

His second group which does not presume a decline in inventiveness, and which merely accounts for an indisposition to patent inventions, probably better accounts for the declining patent rate. Here Dr. Gilfillan presents such factors as the higher standard by which original invention is judged today, the inability sufficiently to define inventions by patents, the unsuitability of the patent system to present-day invention, the increase of monopoly, the larger social views of businessmen (a rather far-fetched reason, this reviewer believes), the changed nature of inventors, and the improvement in the patent bar.

Dr. Gilfillan analyzes these factors and concludes that there is something decidedly wrong in the present patent system. It has failed to develop with the times and remains practically at the stage it started in the 18th century. On the one hand some patents hold up technical progress by assuming monopoly in a certain field. On the other, they fail in most cases to reward the inventor at all. Since 1880, Dr. Gilfillan notes, 65 per cent of the patents brought before the Supreme Court were invalidated. In most cases, as Mr. Kaempffert has remarked, a patent is "nothing more than a right to sue infringers at a ruinous cost."

Something must be done to improve or replace the pa t system and to foster further invention. Dr. Gilfillan recommends a commission to investigate these problems. "Above all," he writes, "the basic reexamination of the patent system, and the encouragement of invention by trade associations with compulsory membership, and the immediate establishment of a New-Industries Committee in the government, seem to merit attention."

Dr. Gilfillan's "Sociology of Invention" will be read by engineers with great interest. It is a valuable contribution to the problem of the relationship between technics and society, and should find a wide audience both in engineering and in sociological circles.

Engineers interested in shipping and students of technical history will also find Dr. Gilfillan's "Inventing the Ship" a valuable study. This volume is an analysis of the development of the merchant ship from early times to the present. The emphasis is upon invention. What inventions were made and how did they affect the development of the ship? How did they affect ship construction? How did the needs of shipping and general social conditions affect the rate and nature of invention? The author treats these problems in a scholarly manner, and while his study may not be as interesting to the casual reader as a more inclusive and more general history of shipping, it will certainly be enjoyed by the classes mentioned.

His discussion of Fulton's place in the development of shipping is well treated and deserves wide attention. Fulton's dependence on the work of Fitch, the Stevenses, Livingston, and the foreign engineers and shipbuilders is well presented, and the question of the relation of the individual to social advance in invention is illumined.

If there is any special drawback to this volume, it is a lack of connection between technical progress and the general culture of the age. To be sure, Gilfillan treats this to some extent, but this reviewer feels that the book would have gained greatly in reader interest (and incidentally as a contribution to the sociology of invention) if more attention were paid to this point.

Heat Calculations for Furnaces

HEAT CALCULATIONS FOR DESIGN AND OPERATION OF FURNACES" (Wärmetechnische Rechnungen für Bau und Betrieb von Oefen) by Dr. W. Heiligenstaedt. Verlag Stahleisen, Düsseldorf, Germany, 1935. Cloth, $5^1/_2 +$ 8 in., 186 pp., 13 illus., and many tables, 11.50 marks.

REVIEWED BY W. TRINKS[2]

THIS little book deserves much praise. It touches upon every engineering problem concerning furnaces in the iron and steel industry, including theory of heat, the heat balance with its various items, combustion (with space requirements for combustion), heat transfer, conduction of heat, with steady and with fluctuating temperatures, heating of the charge in furnaces, and finally heat interchange in recuperators and regenerators.

Heiligenstaedt has done much original work, and some of the chapters such as, for instance, the theory of the process of combustion and of the characteristic properties of burners, are treated for the first time in any publication. Problems such as the cooling of ingots in their molds and the effect of preheat upon heat requirements of open-hearth furnaces are likewise treated. Theories which are well-known are not repeated; the final equation is, however, derived from them and is given conspicuously in large heavy type.

The book is concise and is possibly too much condensed to be of quick and immediate use to the designer or operator. In spite of the care used in presenting final, usable equations, careful study is required to apply them intelligently.

The book is heartily recommended to all furnace engineers who can read German. The beginner will find a wealth of information, and the man well advanced in the profession will find chapters that bring just what he needs to round out his knowledge.

[2] Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa. Mem. A.S.M.E.

Books Received in Library

ADB RICHTLINIEN FÜR DEN VORRICHTUNGSBAU. Zusammengestellt vom Ausschuss für Vorrichtungen der Arbeitsgemeinschaft deutscher Betriebsingenieure im Verein deutscher Ingenieure. By I. Ergänzungslieferung. V.D.I. Verlag, Berlin, 1935. Paper, 9 × 12 in., diagrams, tables, 4.40 rm. These sheets are supplements to the volume on correct methods for the construction and use of machine-tool appliances and accessories which appeared in 1933. They describe clamps for a variety of purposes and illustrate their uses.

AEROPLANE STRUCTURES. By A. J. S. Pippard and J. L. Pritchard. Longmans, Green & Co., New York and London, 1935. Cloth, 6 × 9 in., 368 pp., illus., diagrams, charts, tables, $8.50. This book is intended to give the designer and student of aeronautical engineering a logical, thorough knowledge of the basis of airplane design, with emphasis upon fundamental principles rather than detailed applications. The new edition has been practically rewritten in the light of developments in the theory of airplane structures and in new methods of construction during the last fifteen years. Certain portions devoted to aerodynamics and specifications have been omitted, and new material upon thin-metal construction and the effects of flexibility upon aircraft structures has been introduced.

ALUMINIUMGUSS IN SAND UND KOKILLE. By R. Irmann. Akademische Verlagsgesellschaft, Leipzig, 1935. Paper, 6 × 9 in., 119 pp., illus., diagrams, charts, tables, 6.80 rm. This book provides definite instruction on the making of aluminum castings, and is intended for the practical foundryman. The selection of raw materials, melting, the preparation of sand and permanent molds, and the cleaning, finishing, heat-treatment, and patching of castings are discussed.

ATM, ARCHIV FUR TECHNISCHES MESSEN, LIEFERUNGEN 45–49, March–July, 1935. R. Oldenbourg, Munich and Berlin, 1935. Paper, 9 × 12 in., illus., diagrams, charts, tables, 1.50 rm. each. The text of this work consists of brief reviews of new developments in the field of measurement, reports upon individual methods of measurement, and descriptions of new methods of research. The articles are classified and punched for loose-leaf binders, so that they can be arranged for easy consultation.

Beihefte zum Gesundheits-Ingenieur, Series 1, Part 34. UNTERSUCHUNGEN AN BRIKETTGEFEUERTEN ZENTRALHEIZUNGSKESSELN. By L. Stiegler. R. Oldenbourg, Munich and Berlin, 1935. Paper, 9 × 12 in., 15 pp., illus., diagrams, charts, tables, 3.55 rm. Describes careful tests of three types of heating boilers fired with brown-coal briquettes. The tests were made to ascertain the efficiency of this fuel, the best methods of firing, etc.

BERICHT ÜBER DIE KORROSIONSTAGUNG 1934 am 20 November 1934 in Düsseldorf, prepared by Verein deutscher Eisenhüttenleute, Verein deutscher Chemiker, Deutsche Gesellschaft für Metallkunde, Verein deutscher Ingenieure. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 76 pp., illus., diagrams, charts, tables, 5 rm. This conference was devoted to reports upon our knowledge of pipe corrosion and of methods for preventing it. The action of water, aqueous solutions, and earth upon metals, internal corrosion in water and gas mains, corrosion in hot-water containers, and other related subjects were discussed by specialists.

BERICHTE DES AUSSCHUSSES FÜR VERSUCHE IM STAHLBAU, Ausgabe B, No. 5, DAUERVERSUCHE MIT NIETVERBINDUNGEN. (Deutscher Stahlbau-Verband.) Julius Springer, Berlin, 1935. Paper, 8 × 11, 51 pp., illus., diagrams, charts, tables, 6 rm. In 1928, the German railway and structural-steel interests began an extended study of the fatigue resistance of riveted joints, the results of which have been published from time to time in various periodicals. The present book contains a summary of these results in convenient form for use.

DEUTSCHES MUSEUM Abhandlungen und Berichte, Jg. 7, No. 3, 1935. NEUZEITLICHE KERNPHYSIK UND KÜNSTLICHE UNWANDLUNG DER ELEMENTE. By E. Rüchardt. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 76 pp., illus., diagrams, charts, tables, 90 rm. Within the limits of a pamphlet, the professor of experimental physics at Munich University gives an excellent account of present views regarding nuclear physics and the transmutation of the elements. The paper is simply and clearly written and is intended for the layman, as well as the student.

DIESEL LOCOMOTIVES AND RAILCARS. By B. Reed. Locomotive Publishing Company, London, 1935. Cloth, 6 × 9 in., 190 pp., illus., diagrams, charts, tables, 6s. The author reviews the present situation in the development of Diesel rolling stock in America and Europe. The advantages of Diesel traction, the history of its development, railroad requirements, Diesel engines and auxiliaries, and transmission systems are described. Useful data on costs, efficiencies, etc., are included.

EINFLUSS DES SPANNUNGSZUSTANDES AUF DAS FORMÄNDERUNGSVERMÖGEN DER METALLISCHEN WERKSTOFFE. By A. F. Maier. V.D.I. Verlag, Berlin, 1935. Paper, 6 × 8 in., 47 pp., illus., diagrams, charts, tables, 5 rm. The tests described in this work were undertaken to determine and describe the changes in the plasticity of metals which result from different stresses. Tubular and cylindrical bodies were subjected to polyaxial stresses and tested to rupture. Fatigue tests were also made.

EINFÜHRUNG IN DIE SONDERSTAHLKUNDE. By E. Houdremont. J. Springer, Berlin, 1935. Cloth, 7 × 10 in., 566 pp., illus., diagrams, charts, tables, 52.50 rm. This treatise provides a comprehensive survey of the alloy steels. The effects of the various alloying elements are reviewed systematically, the special properties of each steel are discussed, and methods of heat-treatment described. The author is works manager of the Krupp steel works.

EISEN- UND STAHLLEGIERUNGEN, PATENTSAMMLUNG geordnet nach Legierungssystemen. 1. ERGÄNZUNGSHEFT. By A. Grützner. Zugleich Anhang zur METALLURGIE DES EISENS IN GMELINS HANDBUCH der ANORGANISCHEN CHEMIE, Eighth revised edition. Edited by Deutsche Chemische Gesellschaft. Verlag Chemie, Berlin, 1935. Paper or cloth, 7 × 10 in., 425 pp., tables; paper, 44 rm.; bound, 48 rm. This volume contains a table of the patents for iron and steel alloys which were issued between March, 1932, and December, 1934, by the United States, England, France, Germany, Austria, and Switzerland, and is a supplement to a previous list published in 1932. The patents are grouped by alloys; the composition, the purpose of the patent, and the name of the patentee being given in each case. The book will be valuable to all students of alloy steels.

FANS. By T. Baumeister. McGraw-Hill Book Company, New York and London, 1935. Cloth, 6 × 9 in., 241 pp., illus., diagrams, charts, tables, $3.50. The primary object of this book is to assist the fan user in the selection of the best equipment for any given service conditions. The author first reviews the commercial types that are available. This he follows by a consideration of performance and an analysis of uses, and then discusses the criteria and methods of selection. Chapters are devoted to design and testing, and to the flow of fluids. Each chapter has a bibliography. The book is a welcome addition to the scanty literature on fans.

FORSCHUNGSHEFT 373. DISSOZIATION VON VERBRENNUNGSGASEN UND IHR EINFLUSS AUF DEN WIRKUNGSGRAD VON VERGASERMASCHINEN. By H. Kühl. V.D.I. Verlag, Berlin, 1935. Paper, 8 × 12 in., 18 pp., charts, diagrams, tables, 5 rm. Previous investigators of the influence of dissociation upon the efficiency of gas engines have used values for the specific heats of the gases which were obtained by experiment. In the present study the investigator has used the theoretical values of specific heats and entropy and dissociation constants which are calculated from spectroscopic data, and which vary considerably from the experimental values. The thermal efficiency of the ideal cycle is calculated for various conditions and the effect of dissociation determined.

GENERATING STATIONS, Economic Elements of Electrical Design. By A. H. Lovell. Second edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 438 pp., illus., diagrams, charts, tables, $4.50. The application of economic principles to the problems of the design of generating stations and transmission systems is described. The selection of apparatus, the proportioning of details of the assembly, the balancing of initial and subsequent costs, and related topics are considered. The new edition has been revised in the light of recent developments.

GRUNDFORMEN DER KOSTENRECHNUNG, Beitrag zur Erneuerung des Grundplans der Selbstkostenrechnung. By F. Zeidler. V.D.I. Verlag, Berlin, 1935. Paper, 8 × 12 in., 21 pp., illus., diagrams, charts, tables, 6.50 rm. The principles that underlie all methods of cost calculation are considered in detail and are set forth in a uniform, systematic plan which can be applied to any business. Cost calculation is discussed from a broad point of view. The methods are illustrated by application to various industries; steel works, coal mines, furniture factories, and others.

HEATING AND AIR CONDITIONING. By J. R. Allen and J. H. Walker. Fourth edition. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 444 pp., illus., diagrams, charts, tables, $4. A comprehensive account of fundamental principles and working methods, intended as a text for students of engineering and architecture. The new edition has been thoroughly revised and much new material added to the chapters relating to air conditioning.

HEIZING UND LÜFTUNG, Vol. 1. (Sammlung Göschen 342.) By J. Körting and W. Körting. Sixth edition. Walter de Gruyter & Co., Berlin and Leipzig, 1935. Cloth, 4 × 6 in., 140 pp., diagrams, tables, 1.62 rm. The essential principles of heating and ventilation and the design of installations are presented briefly and practically, for builders and engineers. The new edition has been revised and enlarged.

INTRODUCTION TO QUANTUM MECHANICS. By L. Pauling and E. B. Wilson. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 468 pp., diagrams, charts, tables, $5. This work is intended as a textbook of practical quantum mechanics for chemists, experimental physicists, and beginning students of theoretical physics, especially those without extensive previous experience with advanced mathematics. It aims to provide an easily understandable introduction to the portion of quantum-mechanical theory which consists of the Schroedinger wave equation and the problems that can be treated by it.

DIE KRITISCHEN DREHZAHLEN WICHTIGER ROTORFORMEN. By K. Karas. Julius Springer, Vienna, 1935. Paper, 7 × 10 in., 154 pp., diagrams, charts, tables, 18 rm. The aim of this book is to derive methods and formulas which will enable the designer to calculate the critical speeds of rotors with more exactness than is obtainable by the usual graphical methods. The author discusses especially the question of steam-turbine rotors and endeavors to develop methods and formulas that can be applied rapidly and safely.

MECHANICAL AND ELECTRICAL EQUIPMENT FOR BUILDINGS. By C. M. Gay and C. D. Fawcett. John Wiley & Sons, New York; Chapman & Hall, London, 1935. Cloth, 6 × 9 in., 429 pp., illus., diagrams, charts, tables, $5. The essentials of building equipment, embracing statements of the fundamental theories involved and their broad applications in architectural design are here presented concisely. The book is intended to give architects and architectural students an acquaintance with basic principles, but does not attempt to provide a course in the engineering design of the equipment.

MITTEILUNGEN AUS DEN FORSCHUNGSANSTALTEN GHH-KONZERN, Vol. 3, No. 10, July, 1935. V.D.I. Verlag, Berlin. Paper, 8 × 12 in., illus., diagrams, charts, tables, 3.15 rm, pp. 257–284. The opening paper, by K. Sattler, is a contribution to the theory of

bending in thin plates. The bending of steel sheets subjected to large concentrated loads is investigated, and the stresses determined mathematically. The effect of flanges is also determined, and the applications of the method illustrated by examples. The second paper, by O. Holtschmidt, describes a new machine for vibration tests, developed by the Maschinenfabrik Augsburg-Nürnberg.

MITTEILUNGEN DES FORSCHUNGS-INSTITUTES FÜR WASSERBAU UND WASSERKRAFT e.V. MUNCHEN DER KAISER-WILHELM-GESELLSCHAFT zur FÖRDERUNG DER WISSENSCHAFTEN, No. 3, 1935. R. Oldenbourg, Munich and Berlin, 1935. Paper, 8 × 11 in., 52 pp., illus., diagrams, charts, tables, 3.20 rm. This communication from the Research Institute for Hydraulics contains two reports. The first, by B. Esterer, describes a photoelectric process for analyzing sludges and slimes, which permits the determination of the sizes of the solid particles, as well as their quantity. The application of the process for determining the amount and character of the suspended material in streams is described. The second report, by Dr. H. Schröter, gives a systematic report of the investigations of cavitation as a cause of corrosion which have been in progress for several years at Walchensee.

NOISE, a Comprehensive Survey From Every Point of View. By N. W. McLachlan, with a foreword by Sir Henry Fowler. Oxford University Press, London, 1935. Cloth, 5 × 7 in., 148 pp., illus., diagrams, charts, tables, $2.25. This little book is intended as an introduction to the subject for both lay and technical readers interested in the prevention of noise. What noise is, how it originates, and what are its detrimental effects are discussed in general terms. The text is clear and comprehensive, and an extensive bibliography is provided for those who wish to go more deeply into the subject.

OLD COVERED BRIDGES. By A. M. Jakeman. Stephen Daye Press, Brattleboro, Vermont, 1935. Cloth, 7 × 10 in., 107 pp., illus., $2.50. After a brief outline of the history and construction of covered bridges, the major part of this book is devoted to the existing covered bridges in Massachusetts and Connecticut. Excellent photographs of twenty-six bridges are given, with brief descriptions of each.

PETROLEUM, Twenty-five Years Retrospect 1910–1935, published by Institution of Petroleum Technologists, 1935. Cloth, 6 × 9 in., 219 pp., illus., diagrams, charts, tables, lea., 7s 6d. This volume, devoted to a review of advances in petroleum technology during the years 1910–1935, commemorates the silver jubilee of King George V. The papers, by various members of the Institution of Petroleum Technologists, survey developments in all branches of the oil industry. The occurrence and production of oil, its chemistry and refining, and the transportation and storage of its products are discussed.

POWER OPERATOR'S GUIDE (1001 practical helps). A compilation of ideas, methods, and tools for saving time, labor, and money in the power plant and along the line of power services. Compiled and edited by E. J. Tangerman. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 568 pp., illus., diagrams, charts, tables, $4. A compilation of practical hints upon the operation and maintenance of power-plant machinery, chosen from the columns of *Power*.

PRECISION WORKSHOP METHODS. By H. J. Davies. Edward Arnold & Co., London; Longmans, Green & Co., New York, 1935. Cloth, 6 × 10 in., 306 pp., illus., diagrams, charts, tables, 20s. This volume brings together some of the essential ideas upon which the precise machining of machine parts depends. Methods of setting out work, devices for setting work for machining, graduating and indexing, screw cutting, profiling, cutting gear teeth, lapping and grinding, limit gaging, testing machine tools, and related topics are discussed. The methods described have given satisfaction in practice.

PUBLIC UTILITY QUESTION. By H. G. Hendricks. Published by author at 5629 Kansas Ave., Washington, D. C.; on sale American News Co., New York, 1935. Cloth, 5 × 8 in., 148 pp., tables, $2. The part played by the holding company in the public-utility industry is discussed by a former member of the staff of the House Committee on Interstate and Foreign Commerce. The general features of the utility industry, control, financial structures, the iniquities of holding companies, service institutions, and the political attack on the utilities are treated. The material used is largely taken from Government reports, and presented impartially.

RECHENTAFFLN FÜR WÄRMETECHNIKER, DAMPFKESSELBETRIEB. 40 Rechentafeln mit dreisprachigen Erläuterungen in Deutsch-Englisch-Französisch. R. Oldenbourg, Munich and Berlin, 1935. Paper, 6 × 8 in., 40 pp., charts, tables, 6 rm. A collection of graphic charts covering the principal calculations required in boiler operation and intended to simplify the labors of supervision. Forty charts are provided, dealing with fuel, combustion, water, steam generation and storage, losses, and costs. The meaning of all symbols is given in English and French, as well as German.

REPORTS ON PROGRESS IN PHYSICS. The Physical Society, London. University Press, Cambridge, 1934. Cloth, 7 × 10 in., 371 pp., illus., diagrams, charts, tables, 12s 6d. This attractive volume contains critical, detailed accounts of recent advances in physics up to the end of 1933, prepared by specialists in the various fields of quantum and wave mechanics, classical physics, sound, spectroscopy, optics, heat, X-rays, the physics of the atom, and electric and magnetic measurements. In addition there are special reports on spiral nebulae and the expansion of the universe, Burgers' theory of turbulence, and electric phenomena at extremely low temperatures. The reports are intended to assist the non-specialist to keep abreast of new knowledge and to provide the specialist with a convenient conspectus of recent work. The book is the first of a series of annual progress reports.

SIX-PLACE TABLES, with Explanatory Notes. By E. S. Allen. Fifth edition. McGraw-Hill Book Co., New York and London, 1935. Leather, 4 × 7 in., 175 pp., $1.50. This book presents, in a volume of convenient pocket size, a useful collection of tables of squares, cubes, square and cube roots, circumferences and areas of circles, fifth roots and powers, common logarithms of numbers and trigonometric functions, the natural trigonometric functions and logarithms, radians and degrees, and of exponential, hyperbolic and gamma functions. The type is clear and the paper good.

STEEL WIRE, Manufacture and Properties. By M. Bonzel, introduction by L. Guillet, translated by K. B. Lewis. E. & F. N. Spon, London; Engineers Book Shop, New York, 1935. Cloth, 7 × 10 in., 495 pp., illus., diagrams, charts, tables, $15. This English translation of an important treatise on steel wire is a valuable addition to the scanty literature on the subject. The manufacture of wire is described in detail, step by step, with attention to the scientific aspects, as well as to practical questions. Special attention is given to heat-treatment. The author writes from wide experience.

STRUCTURAL DESIGN OF METAL AIRPLANES. By J. E. Younger, R. H. Rice, and N. F. Ward. McGraw-Hill Book Co., New York and London, 1935. Cloth, 6 × 9 in., 344 pp., illus., diagrams, charts, tables, $3.50. A text for college students covering basic principles and methods of the type of construction in which structural stress members are formed from thin sheets. The text discusses the design problem, available materials, basic structural analysis, and special problems in metal airplane design. The book is the first on the subject.

SYMPOSIUM ON PAINT AND PAINT MATERIALS, Philadelphia Regional Meeting, American Society for Testing Materials, March 6, 1935. Cloth or paper, 6 × 9 in., 150 pp., charts, tables, paper, $1.25; cloth, $1.50. This report contains fifteen papers upon various phases of the paint, varnish, and lacquer industry. The preparation and use of specifications; coatings for railway passenger cars; paint, varnish, and lacquer testing; drying oils; pigments and colors; resins; and solvents and thinners are discussed by various authorities.

TABLES ANNUELLES DE CONSTANTES ET DONNÉES NUMÉRIQUES de Chimie, de Physique, de Biologie et de Technologie. Vol. 10, 1930, part 1. Secrétaire Général, Ch. Marie. Gauthier-Villars, Paris; McGraw-Hill Book Co., New York, 1934. Cloth, 9 × 11 in., 633 pp., charts, tables, $20, for both parts, not sold separately. The "Annual Tables of Constants and Numerical Data" record in one classification the information contained in several hundred important periodicals. The present book is the first of two devoted to the year 1930. An immense amount of information in the fields of physics and chemistry is made available in concise form, with references to the sources. The text is in both French and English. No research library can omit this series.

TECHNOLOGIE DES ALUMINIUMS und seiner Leichtlegierungen. By A. von Zeerleder. Second edition. Akademische Verlags Gesellschaft, Leipzig, 1935. Cloth, 6 × 9 in., 300 pp., illus., diagrams, charts, tables, 12.60 rm. This work is a practical handbook upon the working of aluminum and its alloys, by a well-known expert. After a brief preliminary discussion of the production of the metal and the theory of alloys, the author considers the commercial alloys, their properties and testing. The construction of melting and heating furnaces, heat-treatment, casting, rolling and drawing, forging and stamping, wire making, welding and soldering, riveting and cutting are discussed in a practical manner. There are chapters on the manufacture of aluminum powder, on surface finishing, and on the uses of aluminum alloys. An extensive bibliography is included.

WHAT'S GOING ON

This Month's Authors

L. P. ALFORD, Melville Medallist and member, A.S.M.E., is a well-known author and editor of engineering books, hand books, and periodicals, principally in the field of industrial management. After graduation from Worcester Polytechnic Institute, Mr. Alford laid the foundations for his engineering career in shops in Massachusetts. His editorial experiences commenced in 1907 with the *American Machinist*, of which he was editor-in-chief from 1911 to 1917. In the latter year he became editor of *Industrial Management*, and later of *Management Engineering* and *Manufacturing Industries*.

Mr. Alford's services to the A.S.M.E. and the American Engineering Council are numerous and notable. His name is intimately connected with the well-known reports of the A.E.C., "Waste in Industry," "Twelve-Hour Shift in Industry," "Safety and Production in Industry," and "Technical Changes in Manufacturing Industries." He is known as author or editor of the following: "Bearings and Their Lubrication," "Laws of Management," "Artillery and Artillery Ammunition," and "Management's Handbook." He was a loyal friend and admirer of Henry Laurence Gantt, and author of the biography of that famous engineer in the A.S.M.E. series of biographies. In 1931 he was awarded the Gantt Medal.

Mr. Alford's present paper is the result of his services as engineer to the work-assignment board of the silk and rayon textile industry. For many years he was vice-president of the Ronald Press, New York.

The delightful recollections of O. P. Hood, member, A.S.M.E., prepared as a commencement-day address, reveal so characteristically the kindly philosophy of one of the country's highly regarded engineers that it may almost serve as an introduction to younger men who do not know him personally.

Dr. Hood was one of a small group of engineering students whose admiration and loyalty for the first president of Rose Polytechnic Institute urged them to transfer with him from the institute at Worcester where he had been a teacher and they undergraduates. His life has been spent in consulting practice in mechanical engineering related to mines—older engineers will recall his tests of the Nordberg high-duty air compressor at the Champion copper mine, in Michigan—in teaching at Kansas State Agricultural College, Michigan College of Mines, and in the service of the U. S. Bureau of Mines, where he has been located since 1911. At present he is chief of the technical branch of the Bureau of Mines.

D. G. Williams, member, A.S.M.E., is chief engineer of the Pennsylvania Trojan Powder Co., of Allentown, Pa., where he has been employed since 1914. A graduate of Lehigh University in 1910, Mr. Williams' duties with the Trojan company have included maintenance and construction work, which involved complete change of design, construction, and erection of building, equipment, and special machinery.

Wm. L. De Baufre's interest in air is based on his services as consulting engineer and member of the board of helium engineers, U. S. Bureau of Mines, 1921–1926. He is the inventor of a regenerative system of evaporation; has cooperated in developing process for separating helium from natural gas, and has worked on a process for separating oxygen and nitrogen from atmospheric air. From 1926 to 1931 he was technical advisor and head of the technical research department of the International Combustion Engineering Corporation.

Prior to his Bureau of Mines and industrial experiences, Mr. De Baufre taught at Baltimore Polytechnic Institute, served as mechanical engineer with the U. S. Naval Engineering Experiment Station, and as professor of mechanical engineering at the University of Nebraska. In 1931 he returned to Nebraska, where he is now chairman of the department of applied mechanics. He is a member of the A.S.M.E.

W. M. Dodds, manager of the Taylor Stoker Company, Ltd., London, delivered the paper of which a major portion appears in this issue, while on a visit to this country during the summer.

Sydney Steele, who is at present engaged as a chemical engineer at the Niagara Falls plant of the E. I. du Pont de Nemours & Co., has studied at the University of Cambridge, England, The Johns Hopkins University, and Harvard University. During 1931–1933 he was a guest worker at the National Bureau of Standards, Washington, and in 1933–1934 he held the post of research engineer to Messrs. Imperial Chemical Industries (General Chemicals) Ltd., England.

C. Harold Berry, member, A.S.M.E., Gordon McKay professor of mechanical engineering at Harvard University, is a member of the A.S.M.E. Power Test Codes Committee, and chairman of its technical committee on steam turbines. The subject covered by the paper presented by him this month has been under discussion in his committee for some time, and its consideration by a wide group of readers is desired.

R. E. Freeman is acting head of the department of economics at the Massachusetts Institute of Technology. This is the second of Mr. Freeman's contribution to this series, the other having appeared in the April issue.

A.S.M.E. Completing Plans for 1935 Annual Meeting

SEVERAL innovations in program and operation promise to make the Fifty-Sixth Annual Meeting of The American Society of Mechanical Engineers, to be held as usual in the Engineering Societies Building, New York, N. Y., December 2–6, a memorable event. The Committee on Meetings and Program, with the approval of the Council, and after careful consideration, has made important changes in the social events that should enhance the dignity of certain of these occasions and the interest of members in them.

CHANGES IN NON-TECHNICAL PROGRAM

Public lectures and formal addresses have long been high lights of A.S.M.E. Annual Meetings. The new program arrangement to be put into effect this year will place President Flanders' address on Wednesday evening as a feature of the Annual Dinner, at which R. L. Sackett will act as toastmaster, which will be held as usual at the Hotel Astor. Inasmuch as Mr. Flanders has also been designated the 1935 Towne lecturer, these two addresses will be identical this year. The title of Mr. Flanders' address is "New Pioneers on a New Frontier."

The program for Wednesday evening includes, in addition to President Flanders' address, another by a national figure whose name will be announced later. The President's reception will follow the dinner, while the ballroom is being cleared for dancing.

Tuesday evening will be given over to the presentation of honors and awards, and will be known as Honors Night. A dignified and impressive procedure is being worked out to enhance interest in the important function which the A.S.M.E. performs in honoring its notable members and to emphasize the importance of the bestowal of these honors and awards.

On Honors Night the A.S.M.E., Warner, and Melville Medals will be awarded. The John Fritz Medal, highest award of the engineering fraternity, is bestowed annually, one of the four Founder Societies having the honor every fourth year of representing the recipient. This year the privilege falls to the A.S.M.E. and the medal will be awarded during the ceremonies of Honors Night. The recipient, whose name will be announced at that time, and who is expected to be present in person, is one of the best known and most highly esteemed members of the A.S.M.E.

Collins P. Bliss will act as grand marshal of the ceremonies of Honors Night. Assisting him will be E. H. Whitlock, S. W. Dudley,

James W. Parker, and Kenneth H. Condit. Ushers will be selected from the local sections delegates.

Another change which will provide a more impressive setting for the annual Thurston lecture is the moving of this event from the afternoon to Tuesday evening. This not only will have the advantage of lending greater significance to this event, but will provide more room in the afternoon schedules for the presentation of technical papers. The Thurston lecturer is to be C. H. Purcell, chief engineer of the San Francisco-Oakland Bay Bridge. Mr. Purcell will speak on the construction methods and economics of the San Francisco-Oakland Bridge, one of the major engineering feats of modern times.

Monday, as has been customary in recent years, will be devoted to meetings of the Council and the delegates from the regional conference of local sections that are being held over the country throughout October and November. This arrangement avoids conflicts with attendance at technical sessions, which have been scheduled for the mornings and afternoons of Tuesday, Wednesday, and Thursday. The annual business meeting of the A.S.M.E. is scheduled for Monday afternoon.

On Monday evening, the Metropolitan Section will take charge of the entertainment of the Society's members. A program of high quality and universal interest is being arranged, and the occasion will provide an opportunity for a general get-together early in the busy week at which old acquaintances can be renewed and new ones made.

LECTURES ON TALKING WITH AN AUDIENCE

Members who attended the Annual Meeting in 1933 will recall the helpful and interesting sessions conducted by S. Marion Tucker, of Brooklyn Polytechnic Institute, on talking with an audience. Professor Tucker has generously consented to conduct two sessions on this subject this year. However, instead of the early morning hour before the opening of the technical sessions, the time has been set at 4:30 p.m. on Tuesday and Thursday afternoons. With this arrangement more persons will be able to benefit from Professor Tucker's highly practical talks. Those who have heard Professor Tucker on previous occasions will want to repeat the experience this year and can testify to those who have not heard him of the value of his methods and advice on better public speaking. It has long been a matter of pride with the Committee on Meetings and Programs that it has had the opportunity of making this very practical contribution to the improvement of technical meetings.

EXTENSIVE AND VARIED TECHNICAL PROGRAM

Every year seems to bring forth a technical program surpassing in interest and value programs of previous years. A tentative outline of this year's program will be found in these pages. It is sufficiently accurate to provide a basis for the plans of members who find it advisable to lay out personal schedules in advance. Its varied content should appeal to the interests of all, and the only regret will be that, because of the great number of papers to be presented, simultaneous sessions may make it difficult for a member to hear every paper that may particularly appeal to him. Such conflicts are unavoidable in a society devoting its activities to a broad range of subject matter, but much thought has been given to scheduling events so that there will be a minimum of disappointment on this score.

The Committee on Publications is pleased to announce that every paper submitted to it in time has been preprinted. It will be understood that many of the speakers do not present manuscripts in advance, while unforeseen delays prevent the printing of those received after the deadline date. Every effort has been made to get manuscripts in on time for preprinting. Papers preprinted for the meeting will be found in this and the October issues of MECHANICAL ENGINEERING, and in the October and November issues of the Transactions. Certain other papers have been prepared in photo-offset form. The December issue of MECHANICAL ENGINEERING, which will be received by members near New York just prior to the meeting, will contain other papers. Papers approved for printing but received too late for preprinting will be found in later issues of MECHANICAL ENGINEERING and the Transactions. The program of technical papers printed in these pages provides a key to those that have been preprinted.

Contributions from the A.S.M.E. Professional Divisions and Technical Committees make up the bulk of the technical papers. In many instances committees and divisions have cooperated where the subjects under discussion are of interest to more than one group. In addition, the American Society of Civil Engineers, Federated Management Association, American Society of Refrigerating Engineers, American Ceramic Society, American Society of Heating and Ventilating Engineers, and the Society for the Promotion of Engineering Education are meeting jointly or simultaneously with the A.S.M.E., or are cooperating in some of the A.S.M.E. Annual Meeting sessions. Members of the A.S.M.E. and these cooperating societies are entitled to reduced railway fares to and from New York if hey make use of the railroad certificate provided for that purpose. Further announcement regarding railroad rates will be found elsewhere in these pages.

In addition to the large number of papers of strictly engineering interest, the program lists several sessions devoted to subjects of importance to human relations and industrial management. A session on psychology will provide a symposium on the effect of technological change on human relations. Others will be devoted to compensation laws, occupational diseases, and work assignments in the silk industry, all topics of timely significance because of emphasis that is being placed in the country at large on labor relations.

REGISTRATION BADGE MUST BE SHOWN AT SESSIONS

For numerous reasons every person attending a session will be required to show the identification badge which he receives when he registers. For the convenience of those arriving too late to register on the main floor before the beginning of a session they particularly wish to hear, arrangements have been made for a preliminary registration at every meeting room. Thus the committee will be sure of securing a record of every one who comes to the meeting, but delays and inconvenience will be reduced to a minimum. For non-members a fee of one dollar will be charged. For this fee the non-member receives a registration badge which admits him to any and all of the public events and technical sessions.

NEW PUBLIC-ADDRESS SYSTEM TO BE USED

Use will be made for the first time of the improved public-address system and movietone projector with which the Engineering Societies Auditorium was equipped this fall. This equipment is of the very latest and most improved design and will add greatly to the pleasure of the audience, as by means of it speakers can be heard, in natural voice, in every part of the auditorium, and motion pictures in color and with sound effects can be used.

The equipment, which was demonstrated to officers of the United Engineering Trustees and the engineering societies in September, has thoroughly modernized the auditorium for public-meeting purposes. A microphone, permanently attached to the reading stand, so successfully and naturally augments the speaker's voice that he may talk in ordinary tones and yet be heard perfectly throughout the hall without the disturbing effect, noticeable in some systems, of appearing to originate in several places because of several differently located loud speakers.

In addition to the microphone at the reading desk, a second portable instrument can be placed wherever desired on the stage or on the sub-platform in front of the stage where discussors of papers customarily stand when speaking. Thus wherever the speaker may be, on the floor of the auditorium or at the back of the stage describing pictures thrown on the screen, he is heard perfectly. A third device, a lapel microphone equipped with a long cord, is available for speakers who do not wish to be confined to the reading stand. Thus, if the speaker wishes to address the audience from any point on the stage, to describe pictures on the screen, to use a black board, or to demonstrate apparatus set up to assist his presentation, he may do so without fear of not being heard. Moreover, his speech is not affected should he find it necessary to turn away from the audience.

MANY TECHNICAL COMMITTEES TO MEET

As usual, the week will provide opportunity for numerous meetings of the Society's many important technical committees. Announcement of the times and places will be received by members of these committees in advance as a matter of committee procedure, and will be found in the official program distributed at the meeting. As a courtesy to members of these committees who are not members of the Society, no registration fee will be charged, and they are invited to participate in as many of the Society's activities as their time and interests permit.

EXCURSION PROGRAM BEING ARRANGED

A varied program of excursion and visits to plants in the Metropolitan area is being arranged. Announcement of these will be made later, and opportunity will be provided to sign up for as many as the individual's program permits. Arrangements can also be made, as in the past, for individuals to visit plants and points of interest to him not included among those officially scheduled. The committee which has charge of the excursions is under the chairmanship of Charles Peace.

WOMEN WILL HAVE A GOOD TIME

A committee is actively at work on a program for the women. Headquarters and a special reception committee have been arranged so that every woman attending the meeting will find herself cordially welcomed and amply provided with interesting entertainment while members are attending technical sessions and committee meetings. The formal events of Tuesday, Wednesday, and Thursday nights will prove enjoyable to both men and women, especially the dinner, presidents' reception, and dance on Wednesday. Special programs for the women will be distributed on registration. No registration fee is charged. Mrs. Arthur Bruckner is chairman of the committee on arrangements.

POST-CONVENTION CRUISE TO BERMUDA

A post-convention cruise to Bermuda is being planned for those who are able to avail themselves of an opportunity to take an early winter holiday in company with congenial companions. The post-convention cruise has been tried with success by the American Institute of Mining and Metallurgical Engineers, and the American Society of Civil Engineers. It is understood that both these societies will arrange cruises for their members following their conventions this winter.

The post-convention cruise for mechanical engineers will be of seven days' duration, leaving New York on Saturday, December 7. Nearly three days on the island are provided. The minimum charge is $71 for the seven days. This is a special price offered for this cruise. Higher rates are charged if more luxurious accommodations are desired on the ship, but members of the cruise will be granted discounts of from 10 to 25 per cent from the regular prices of these quarters.

Program of Technical Sessions

TUESDAY, DECEMBER 3

9:30 a.m. Machine Shop

Desired Characteristics of Surface Finishes, by J. E. Kline

Steel-Plate Structures Vs. Cast Iron, by R. T. Hazelton

9:30 a.m. Psychology

Human Relations and Technological Changes

The Place of Skill in Industry, by Lillian M. Gilbreth

Human Problems as Created by the Introduction of Labor-Saving Machinery, by Elizabeth F. Baker

What Is the Effect on Employees of Technological Changes, by M. S. Viteles

The Development of Physiological Efficiency and the Maintenance of Health When Introducing a Technological Change, by Howard W. Haggard

Methods of Introducing Technological Changes, by C. S. Ching

9:30 a.m. Railroad

Measurement of Steam Rate and Indicated Horsepower of Locomotives, by Arthur Williams*

Progress in Railroad Mechanical Engineering, by Progress Report Committee, A. I. Lipetz, Chairman

9:30 a.m. Hydraulics

Cavitation and Erosion Investigated as a Problem in Fluid Mechanics, by W. Watters Pagon (Photo-offset copies of extended abstract available)

Progress Report on Cavitation Research at Massachusetts Institute of Technology, by J. C. Hunsaker*

Progress in Cavitation Research at Princeton University, by L. F. Moody and A. E. Sorenson*

9:30 a.m. Sugar

Symposium on Automatic Control of Boiling Sugar

9:30 a.m. Mechanical Springs

Maximum Shearing Stresses in Eccentrically Loaded Helical Springs of Circular Wire, by H. C. Perkins

Correlation of Spring-Wire Bending and Torsion Fatigue Tests, by E. E. Weibel*

Report on Fatigue Tests on Helical Springs

12:30 p.m. Job-Shop Luncheon

Small Job-Shop Planning and Scheduling Control of Production Hours in Engineering Department

2:00 p.m. Power

Cause and Prevention of Turbine-Blade Deposits, by F. G. Straub*

An Airfoil-Type Propeller Blower for Ventilating Electrical Machines, by C. E. Peck and M. D. Ross*

2:00 p.m. Process

Influence of the Double Eddy Current on the Design of Dust Collectors, by H. van Tongeren

2:00 p.m. Railroads

Locomotive and Car Journal Lubrication, by E. S. Pearce

2:00 p.m. Hydraulics

Cavitation Testing of Model Hydraulic Turbines and Its Bearing on Design and Operation, by L. M. Davis*

Cavitation Testing on Propeller Pumps, by A. Tenot

2:00 p.m. Psychology

Discussion continued of papers presented at morning session

2:00 p.m. Applied Mechanics

Design Aspect of Creep, by R. W. Bailey

A Method of Analyzing Creep Data, by R. G. Sturm, C. Dumont, and F. M. Howell

The Creep of Metals, by A. Nadai and E. A. Davis

Residual Stresses in Cold-Drawn Brass Tubes, by C. G. Anderson

WEDNESDAY, DECEMBER 4

9:30 a.m. Power

Steam-Turbine Testing, by C. H. Berry (Published in the November, 1935, issue of MECHANICAL ENGINEERING)

The Flow Characteristics of Variable Speed Reaction Turbines, by A. Egli

The Viscosity of Water and Superheated Steam, by G. A. Hawkins, H. L. Solberg, and A. A. Potter*

9:30 a.m. Occupational Disease

The Additional Responsibility Placed Upon Industry by Recent Occupational-Disease Legislation, by H. Sayer

Engineering Control of Occupational-Disease Hazards, by Warren Cook

Uses and Limitations of Protective Devices and Equipment, by Philip Drinker

9:30 a.m. Metal Cutting

A Study of the Turning of Steel Employing a New Type Three-Component Dynamometer, by O. W. Boston and C. E. Kraus

The Torque and Thrust of Small Drills Operating in Various Metals, by O. W. Boston and W. W. Gilbert

9:30 a.m. Petroleum

Control Apparatus in Oil Refinery, by Harry F. Moore

Heat-Recovery Design for Petroleum Refineries, by N. T. Buddine (Photo-offset copies available)

9:30 a.m. Iron and Steel

Bearing Investigation by the Varying Wear Method, by J. R. Connelly and C. C. Hertel (Photo-offset copies available)

Discussion of Pressure-Indicating and Control Equipment for Rolling Mills, led by F. Buckingham and S. B. Terry

9:30 a.m. Textiles

Power Applications and Other Mechanical Features in Connection With Textile Printing, by R. DeVere Hope

* Papers marked with asterisk are being published either in the October or November, 1935, issues of A.S.M.E. Transactions.

Discussion on Application of Printing Ink to Textile Printing, led by Albert E. Gessler

12:30 p.m. Textile-Management Luncheon

Work Assignment in Silk and Rayon Manufacturing, by L. P. Alford (Published in the November, 1935, issue of MECHANICAL ENGINEERING)

2:00 p.m. Power

Stresses in Three-Dimensional Pipe Bends, by William Hovgaard*

Creep of Steels as Influenced by Microstructure, by L. L. Wyman (Published in the October, 1935, issue of MECHANICAL ENGINEERING)

2:00 p.m. Compensation Laws

Present Status of Workers' Compensation Laws, by F. Robertson Jones, Frederick S. Kellogg, and Austin J. Lilly

2:00 p.m. Locomotives

Lateral Oscillations of Rail Vehicles, by B. F. Langer and J. P. Shamberger*

Safe Operation of High-Speed Locomotives, by B. S. Cain*

2:00 p.m. Boiler Furnaces

An Experimental Investigation of Heat Absorption in Boiler Furnaces, by W. J. Wohlenberg, H. F. Mullikin, W. H. Armacost, and C. W. Gordon*

Review of Methods of Computing Heat Absorption in Boiler Furnaces, by W. J. Wohlenberg and H. F. Mullikin*

Evaluation of Effective Radiant Heating Surface and Application of the Stefan-Boltzman Law to Heat Absorption in Boiler Furnaces, by H. F. Mullikin*

2:00 p.m. Fan Test Code

The Measurement of Air Flow in Fan Inlet and Discharge Ducts, by L. S. Marks*

The Definition of the Quantity-Head Characteristics of Fans, by M. C. Stuart and W. E. Somers*

THURSDAY, DECEMBER 5

9:30 a.m. Fuels

Factors in the Selection of Coal for Underfeed Stokers, by R. L. Rowan, L. A. Shipman, T. H. Queer, K. J. Kasper, O. O. Mallers, and J. E. Tobey, committee of fuel engineers representing Appalachian Coals, Inc. (Photo-offset copies available)

Symposium on Zoned and Metered-Air Control for Underfeed Stokers, by H. E. Macomber, A. S. Griswold, and J. N. Landis

9:30 a.m. Costs

Fundamentals of Cost Accounting, by Charles Reitell

Industrial Production Costs, by E. S. LaRose

9:30 a.m. Applied Mechanics

Fatigue of Cold-Rolled Specimens, by O. J. Horger and J. L. Maulbetsch

Rate of Development of Fatigue Cracks in Steel, by A. V. deForest

Mechanical Properties of Bakelite and Its Behavior at Failure, by M. M. Frocht

Marblette as a New Photoelastic Material, by A. G. Solakian

9:30 a.m. Aeronautics

The Design and Performance of a High-Pressure Axial Flow Fan, by L. S. Marks and Thomas Flint*

Pressure Losses in Rectangular Elbows, by Richard D. Madison and J. Richard Parker

The Rating of Aircraft Engines, by Gaylord W. Newton

9:30 a.m. Radiant Heat

Heat Transfer in Steel Re-Heating Furnaces, by J. E. Eberhardt and H. C. Hottel

Radiation From Non-luminous Flames, by H. C. Hottel and V. C. Smith*

Tests of Radiation From Luminous Flames, by W. Trinks and J. D. Keller

9:30 a.m. Wood Industries

The Use of Timber Connectors, by P. A. Hayward

Discussion of Pre-Framing and Treatment of Structural Timbers

Discussion of Machinery for the Pre-Framing of Structural Timbers, led by Leslie Geddes

Visit to demonstration of one-hour fire test of fire-retardant wood door

2:00 p.m. Fuels

The Life of Various Types of Furnace Bottoms for Tapping Ash in the Molten State, by Rolfe Shellenberger

Water-Cooled Stokers, by J. S. Bennett and C. J. Herbeck

Electrostatic Precipitators for Stoker-Fired Boilers, by C. W. Hedberg

2:00 p.m. Costs

Industrial Production Costs, by C. H. Knapp

Power-Distribution Costs, by Morris L. Cooke

2:00 p.m. Oil and Gas Power

Film-Lubrication Theory and Engine-Bearing Design, by E. S. Dennison

Ignition and Combustion of Diesel Fuels, by G. D. Boerlage and J. J. Broeze (Photo-offset copies available)

Oil-Engine-Electric Generating Station Operating Costs, by George C. Eaton (Photo-offset copies available)

1934 Cost Data Report (Copies on sale)

2:00 p.m. Applied Mechanics

Analysis of Plate Examples by Difference Methods and the Superposition Principle, by D. L. Holl

Buckling and Ultimate Strength of Compressed Rectangular Plates, by S. Timoshenko

An Experimental Towing Test for Small Models, by K. S. M. Davidson

2:00 p.m. Boiler Feedwater

The Use of Solubility Data to Control the Deposition of Sodium Sulphate or Its Complex Salts in Boiler Waters, by W. C. Schroeder, A. A. Berk, and Everett P. Partridge

Estimation of Dissolved Solids in Boiler Water by Density Readings, by J. A. Holmes and J. K. Rummel

Suspended Solids in the Foaming and Priming of Boiler Water, by C. W. Foulk

The Effect of Solutions on the Endurance of Low-Carbon Steel Under Repeated Torsion at 482 F (250 C), by W. C. Schroeder and Everett P. Partridge

Embrittlement of Boiler Steel by Caustic Soda, by G. H. Wagner and J. R. Wall

A Study of the Effect of Concentrated Sodium Hydroxide on Boiler Steel Under Tension, by A. S. Perry

2:00 p.m. Radiant Heat

Emissivities of Refractory Materials, by R. H. Heilman

A Radiometric and Pyrometric Study of Diffusion Flames, by M. A. Cooper and H. C. Hottel

Radiation From Pre-Mixing Burner Flames in Combustion Chambers, by E. O. Mattocks

A Study of Methods for Measuring Flame Temperature in an Internal-Combustion Engine, by A. E. Hersey

REDUCED RAILROAD RATES

MEMBERS of The American Society of Mechanical Engineers planning to attend the 1935 Annual Meeting in New York, December 2 to 6, should secure certificates which will entitle them to return tickets at the rate of one-third the regular one-way fare. Certificates must be validated at the headquarters of the Society during the meeting. The return ticket must be purchased by December 10. Tickets so purchased will then be good for return passage to reach the original starting point within thirty days from the date of sale of the going ticket as shown on the certificate. It will, of course, be necessary to return by the going route. The one-third fare return rate will be available to members of The American Society of Mechanical Engineers, the American Society of Civil Engineers, Federated Management Association, American Ceramic Society, the Society for the Promotion of Engineering Education, the American Society of Heating and Ventilating Engineers, and the American Society of Refrigerating Engineers.

C. F. Scott Heads E.C.P.D.

CHARLES F. SCOTT, professor-emeritus of electrical engineering, Yale University, and chairman of the board appointed by Governor Cross to administer the recently enacted engineers' registration law in the State of Connecticut, was elected Chairman of the Engineers' Council for Professional Development at the Third Annual Meeting of that body held in New York, N. Y., on October 8. Professor Scott succeeds C. F. Hirshfeld, chief of research of the Detroit Edison Company, who has served as the Council's Chairman since its formation in 1932.

The Engineers' Council for Professional Development is a conference of engineering bodies organized to enhance the professional status of the engineer through the cooperative support of the national organizations directly representing the professional, technical, educational, and legislative phases of the engineer's life. The participating bodies are: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society for the Promotion of Engineering Education, American Institute of Chemical Engineers, and National Council of State Boards of Engineering Examiners.

George T. Seabury, secretary of the American Society of Civil Engineers, was reelected secretary of the Council. New members of the executive committee also elected were C. F. Hirshfeld, representing The American Society of Mechanical Engineers, Harrison P. Eddy, of Boston, Mass., past-president of the American Society of Civil Engineers, representing that society, and L. W. W. Morrow, editor of the *Electrical World*, New York, N. Y., representing the American Institute of Electrical Engineers. Other members of the executive committee who continue in office and the societies they represent are F. M. Becket, of New York, past-president of the American Institute of Mining and Metallurgical Engineers, H. C. Parmelee, of New York, American Institute of Chemical Engineers, R. I. Rees, of New York, Society for the Promotion of Engineering Education, and D. B. Steinman, of New York, National Council of State Boards of Engineering Examiners.

After the meeting adjourned the annual dinner, at which the chairman, C. F. Hirshfeld presided, was held at the Engineers' Club, attended by about 30 representatives of the participating bodies and guests of the Council. A résumé of the work of the Council's four principal committees and of the actions of the Annual Meeting was reported by Mr. Hirshfeld. Professor Scott spoke on the significance of the Council's activities in carrying forward its program in a spirit of understanding and cooperation.

At the Annual Meeting reports of the Committees were presented and approved. These reports will be made public when printed for distribution. The four committees under whose guidance the principal activities of the Council are conducted have been set up to cover the four phases of the engineer's training. These are Student Selection and Guidance, charged with the pre-collegiate phases; Engineering Schools, whose interests at present are directed toward carrying out a program of accrediting engineering curricula; Professional Training, which gives its attention to the problem of the young engineer and recent graduate; and Professional Recognition, whose concern is with procedures by which the individual becomes a recognized member of the engineering profession.

Because of misunderstandings of the purposes and objectives of the Committee on Professional Recognition which had arisen since the 1934 Annual Meeting, the Council adopted a resolution in which it regretted and disclaimed any statement that had been made in its behalf that might have been construed as unfriendly toward the engineers' registration movement, and any intention to set up a certifying agency in conflict with the legal registration of engineers by state boards or to parallel or supplant the National Bureau of Engineering Registration.

At the request of the Committee on Professional Recognition its "Program of Certification," adopted by the Council in October, 1934, was referred back to the committee for further study and clarification.

A.E.C. News From Washington

THE approval of projects under the Federal work-relief program has been speeded up in recent weeks to make work available against the winter peak in operations. Discontinuance of the Division of Applications and Information, and clarification of functions of the Advisory Committee on Allotments, seem to place broad discretionary power under the state administrators and directors as to the carrying out of approved projects and the advancement of projects not yet approved.

Engineers interested in individual projects should be reminded that the President insists upon the certification of each project by the Comptroller General and conditions his approval upon that certification. It is further noted that numerous projects have been rescinded after their conditional approval.

DEVELOPMENTS IN WPA

The Works Progress Administration, the largest spending and employing agency of the program, has been given a high degree of flexibility through the approval of approximately twice as many projects as there is money to finance. Each state has a pool of projects from which to draw in placing the jobless in work suited to individual skills, with latitude as to the selection of projects at the time and place most needed. State administrators have been told that they must, in so far as possible, give work to all eligibles; must finish projects or project units once begun; and must plan purchases of materials so as to avoid either a shortage or a surplus. The expectation is that WPA will handle work aggregating more than $1,000,000,000.

Of primary importance is the entrance of the Corps of Engineers of the Army into the WPA program. Lt-Col. F. C. Harrington has been appointed chief engineer of WPA. Officers of the Corps have been appointed consulting field engineers in eleven areas of the United States. The consulting field engineers soon will visit their areas to secure full information as to the works program in each state, with "particular regard to those obstacles or difficulties which are hampering the speedy development of the program."

Specialized WPA phases of engineering significance include water conservation and irrigation projects now authorized for state WPA programs. Airports under WPA are subject to the approval and technical supervision of state representatives of the U. S. Bureau of Air Commerce. Planning, statistical, and research projects may be sponsored by state planning boards, aided by the state planning consultants of the National Resources Committee. Area statistical offices are being established to serve as clearing houses for reports on the work of all Federal agencies entering the work-relief program in the respective areas.

ACTIVITIES OF PWA

The Public Works Administration is going forward with a new program involving between 3000 and 4000 projects in which Federal grants from new money and loans from the PWA revolving fund amount to about $500,000,000. With the addition of funds which the project sponsors have secured by private borrowings, the program amounts to about $750,000,000 of new construction. In addition, numerous projects are in various stages of construction under the former PWA program.

Project sponsors have been warned that they must have contracts let and must be ready to start work on their PWA projects by the December 15 deadline set by the President. Otherwise, their projects are likely to be rescinded and the funds transferred to other worthy jobs for which PWA has applications on file.

CCC IS CONTINUED

Indefinite continuation of the Civilian Conservation Corps is contemplated in plans which call for a tapering off of enrolment from a peak of about 600,000 to 300,000 next July. Of approximately 750,000 young men who finish their formal education each year, some 600,000 are employable. On the basis discussed, the corps could offer half of these a year of out-of-door work at some time in their young manhood. The age limit for enrollment, originally 18 to 25, has been widened from 17 to 28. WPA also plans to employ young men and women from 16 to 25, especially those from large relief families, to supplement the primary earnings of heads of families that are carried under the work program.

Developments under WPA, PWA, and CCC have tended to overshadow the work of many other Federal Agencies whose part in the program is of continued interest to engineers. Further announcements from these agencies should be watched for in the next few weeks.

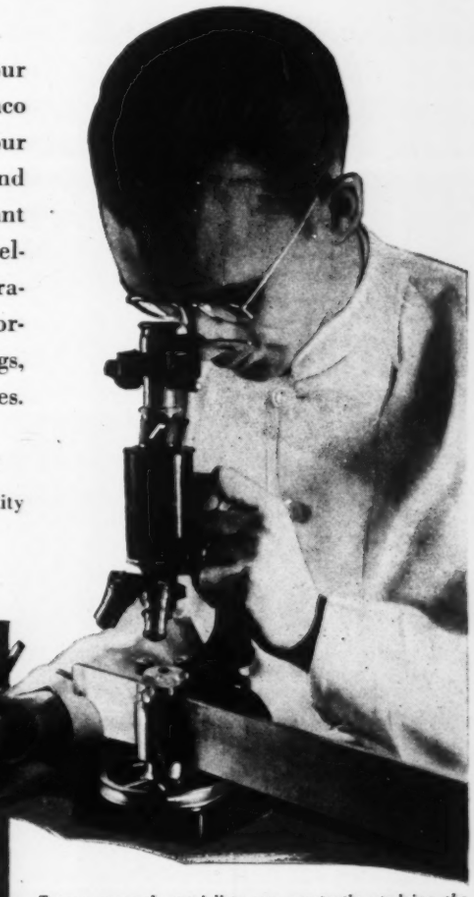
We keep BEARINGS *bearing up instead of bearing down!*

A bearing out of service means a machine out of production. By using the lubricant best suited to a particular operating condition, or type of bearing, you can minimize this hazard.

Through an interchange of ideas and constant contacts with bearing designers and manufacturers in addition to extensive scientific research in The Texas Company's own laboratories we have developed a complete line of tested and proved lubricants that fit exactly every bearing condition in your plant. Remember that the Texaco representative is trained to aid your men in the proper selection and use of the most effective lubricant for any condition. They will welcome his friendly, helpful cooperation because it means an opportunity for them to show new savings, and greater operating efficiencies.

THE TEXAS COMPANY
135 East 42nd Street • New York City

Nation-wide distribution facilities assure prompt delivery.



Texaco research specialists are constantly studying the problems of lubrication, developing new lubricants to meet new conditions. Let a Texaco representative tell you about this work and the benefits to your plant.

JUST A FEW EXAMPLES

1. Rolling Mill Bearings • Here heat and tremendous pressures play havoc with unsuitable lubricants. Texaco has solved this difficult lubrication problem for many of the country's foremost mills.

2. Paper Mill Bearings • The efficient lubrication of paper machines presents a wide variety of conditions requiring close specialized study. These bearings call for exacting attention to conditions of speed, pressures, moisture and temperature. There is a proved Texaco Lubricant exactly right for every bearing in the plant.

3. Textile Mills • Lighter bearings operating at high speeds seem a comparatively simple problem. Cotton spindles, for instance, represent just one of them. Texaco has developed a series of remarkably efficient bearing lubricants for textile mills. They have effected power savings in many plants.

TEXACO
REG. T. M.

TEXACO *tested* LUBRICANTS

REFINERY TESTED FOR UNIFORMITY • • • SERVICE TESTED FOR ECONOMY

NEW MEMBERS FOR A.E.C.

Membership of the American Engineering Council continues to grow under the new plan of nominal dues to enable more state and local societies to participate in Council's activities. New members include: The Engineers Club of Baltimore, Maryland Association of Engineers, South Carolina Society of Engineers, and the Associated Engineers of Spokane. This will give Council a total of 30 state and local members, an increase of 15 since the new plan went into effect last January.

Actions of A.S.M.E. Executive Committee

AT the September 18 meeting of the Executive Committee of The American Society of Mechanical Engineers the following actions of general interest were taken:

TOWNE AND THURSTON LECTURERS FOR 1935

Upon the recommendation of the Committee on Meetings and Program, Ralph E. Flanders, president, A.S.M.E., and C. H. Purcell, chief engineer, San Francisco-Oakland Bridge Authority, San Francisco, Calif., were selected as Towne and Thurston lecturers, respectively, at the 1935 Annual Meeting of the Society.

ENGINEERING SOCIETY OF PENNSYLVANIA

It was voted to approve an exchange of courtesies with the Engineers Society of Pennsylvania, whose headquarters are at Harrisburg, Pa.

RELATIONS WITH FOREIGN SOCIETIES

Reports on relations with foreign societies were reported as follows:

Société Belge des Ingénieurs et des Industriels: Laurence V. Benét, who represented the Society at the fiftieth anniversary, June 13–15, 1935, Brussels, reported that he had had an opportunity to convey the congratulations of the A.S.M.E. and had sent two volumes of the proceedings and the commemorative medal.

Institution of Electrical Engineers of Japan: Dr. D. C. Jackson who will be in Japan as Iwadare Lecturer, will present to the Institute of Electrical Engineers of Japan the official greetings of the A.S.M.E.

Tokyo Imperial University: Dr. H. Foster Bain conveyed message of greeting to the Society from Dr. Masawo Kamo of Tokyo Imperial University, Tokyo, Japan.

North East Coast Institution of Engineers and Shipbuilders: Letter of appreciation received for official greetings sent by the A.S.M.E. on the occasion of its Jubilee Meeting, July 16, 1935, England.

APPOINTMENTS

The following appointments were reported for record:

Education and Training for the Industries, Warner Seely (to fill unexpired term of P. E. Bliss, 1939). Safety Committee, Junior Advisor, Carl Endlein. Tellers of Election, F. E. Dean, T. F. Du Puy, T. R. Thomas, and J. V. V. Colwell, alternate. National Defense Division Executive Committee, Howard E. Coffin. Special Committee on Registration Procedure, James H. Herron, chairman, John A. Hunter, and James M. Todd. Committee on Medals (appointments for five-year term), E. O. Eastwood, A. M. Greene, Jr., D. C. Jackson, R. H. Fernald, K. H. Condit, R. V. Wright, R. H. Sibley, J. H. Herron, J. Lyle Harrington, F. M. Gunby, H. C. Meyer, Jr., J. W. Parker, C. L. Bausch, E. R. Fish, L. W. Wallace, and members of the Committee on Awards.

E.C.P.D. representative, W. E. Wickenden (three-year term). A.E.C.'s Committee on Water Power Policy, W. F. Uhl. Second National Convention of Mechanical and Electrical Engineers of Mexico, August, 1935, Bernardo Avalos Vez. American Scientific Congress, Mexico City, September 8–17, 1935, Bernardo Avalos Vez.

Heat-Transfer Classification Proposed

A TENTATIVE classification of the subject of heat transfer has been prepared by the Heat Transfer Committee of the Process Industries Division, of The American Society of Mechanical Engineers. The subject has been conveniently divided into three main classes: Physics of heat transfer, unfired processes and apparatus, and direct fired processes and apparatus.

The complete classification, which is given below, is now offered by the committee for study and discussion. Although tentatively adopted by the committee, it is subject to change, and suggestions are solicited. At the coming Annual Meeting of the A.S.M.E. the committee plans to arrange for a thorough discussion of the proposed classification. The classification itself will be useful to the committee in laying out a comprehensive program of papers on this important engineering subject.

HEAT-TRANSFER CLASSIFICATION

Class 100—Physics of heat transfer. Physical phenomena and physical constants for thermal and use properties of source, receiver, or carrier materials, and materials of the structure.

Class 200—Unfired processes and apparatus. Transfer from any source other than (300) to any receiver.

Class 300—Direct-fired processes and apparatus. Release of heat by combustion (or other reaction or electrically), and transfer to any receiver.

CLASS 100—PHYSICS OF HEAT TRANSFER

10 Physical properties of materials of heat transfer as functions of temperature.

20 Experimental methods and instruments for measuring heat-transfer rates, temperatures, and other quantities involved in heat release and transfer.

30 Physical phenomena of heat transfer by conduction, convection, and radiation in relation to temperatures.

40 Thermal expansion of solids. Temperature stresses and effect of temperature on stress resistance.

50 Transfer across boundary of boiling liquid.

60 Transfer across boundary of condensing vapor.

70 Transfer across boundary of fluid in turbulent flow with and without radiation. Enclosures and submerged bodies.

80 Transfer across boundary of fluid with natural convection motion with and without radiation.

90 Transfer across boundaries of vapor-gas mixture and mixed vapors changing vapor concentration.

CLASS 200—UNFIRED PROCESSES AND APPARATUS

10 Solid sources and receivers, steady and unsteady state, including walls and walled enclosures. Insulation.

20 From a condensing vapor as a source to different fluid receivers, liquids, boiling liquids, or gases.

30 From a liquid (not changing state) as a source to different fluid receivers.

40 From a gas or superheated vapor as a source to different fluid receivers.

50 Vapor-gas mixtures and mixed vapors changing vapor concentration as sources or receivers, with other fluids as receivers and sources.

60 Complex and mixed sources and receivers.

CLASS 300—DIRECT-FIRED PROCESSES AND APPARATUS

10 Heat release by combustion in furnaces. Rates and temperatures. Flames as primary sources of heat. Electric equivalents.

20 Direct-fired liquid heaters and saturated-steam boilers as low-temperature receivers.

30 Direct-fired gas heaters, vapor superheaters, and boilers for high-boiling-point liquids.

40 Superheated-steam power boilers, with or without economizers and air heaters.

50 Low-temperature solid heaters, of oven, drier, and melter type.

60 Metal heaters, reheaters, and melters, medium and high temperature.

70 Medium- and high-temperature heaters of non-metallic solids, of ceramic-kiln, ore-roaster, and coal-carbonizing types.

80 Smelting furnaces.

Election of A.S.M.E. Officers for 1936

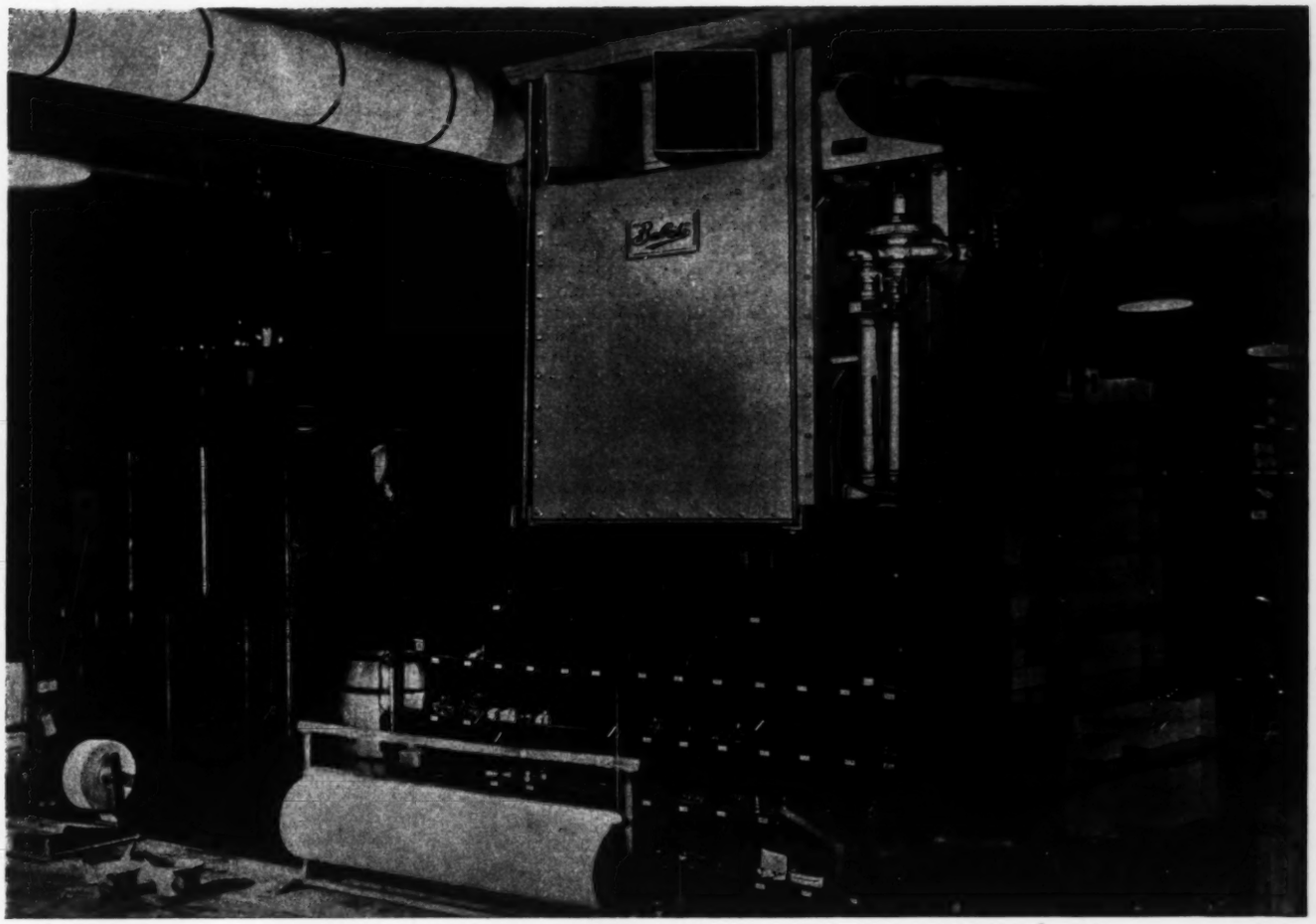
THE result of the election of officers of The American Society of Mechanical Engineers for 1936 is as follows:

Office	Nominee	Votes
President	WILLIAM L. BATT	3185
Vice-Presidents	ALEX D. BAILEY	3191
	JOHN A. HUNTER	3190
	ROBERT L. SACKETT	3191
	WILLIAM A. SHOUDY	3186
Managers	WILLIAM LYLE DUDLEY	3195
	WALTER C. LINDEMANN	3194
	JAMES W. PARKER	3188

Biographical sketches of the nominees for office may be found on pages 527–530 of the August, 1935, issue of MECHANICAL ENGINEERING.

Aeronautics Study Group

THE Aeronautics Study Group of the Junior members of the A.S.M.E. Metropolitan Section met on September 10 to dis-



This BUFFALO GAS UNIT HEATER supplies heat for a large storeroom

Put CLEAN, ECONOMICAL Gas Heat on the job this winter—

Gas heat has real advantages for the industrial user today—First, Buffalo Gas Unit Heaters burn natural or artificial gas, efficiently. Second, they provide CLEAN heat, no dust, smoke or ashes. Third, initial cost is low, no boiler room, fuel storage or auxiliary equipment is required. Fourth, automatic safety features and temperature control provide economical gas consumption.

Many Buffalo Gas Heaters are used as auxiliary heating equipment, in storerooms, warehouses, garages and buildings where the original heating system is inadequate.

Write us for detailed information on the two styles and four sizes available.

We Also Manufacture Complete Lines of

Steam Unit Heaters

Write for Bulletins.

Buffalo Forge Company
148 Mortimer St., Buffalo, N. Y.
In Canada: Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo"

GAS UNIT HEATERS

cuss plans for the coming year. This group was formed last year to keep abreast of developments in aviation, to meet engineers in that field, and to enable its members to gain experience in formal presentation of papers. The officers of the group are: Robert M. Frank, chairman; William B. Pegram, vice-chairman; and John S. Irwin, secretary.

The programs of the group, to which all junior and senior members of the Metropolitan Section are invited, will include talks by prominent men in the field of aviation, as well as by members of the group, open forums and inspection tours. For further information address the secretary, Aeronautics Study Group, John S. Irwin, in care of the A.S.M.E., 29 West 39th St., New York, N. Y.

Coming Meetings of A.S.M.E. Local Sections

Kansas City: December 5, 1935. Joint Meeting of A.I.E.E. and A.S.M.E. with Student Branches of both societies at Lawrence, Kansas. Four papers will be presented by students, and a fifth paper by a member of the Kansas City Section Junior Group.

Philadelphia: January, 1936. The Engineers Club of Philadelphia, 1317 Spruce St., Philadelphia, Pa. Subject: Non-Ferrous Metal Materials. Definite date will be announced later.

Mechanical Catalog Issued

THE twenty-fifth annual Mechanical Catalog, Silver Anniversary Number, was published on October 1 by the American Society of Mechanical Engineers. This issue shows a considerable improvement over the preceding one, both in number of pages of product descriptions carried and in make-up, a new feature being introduced this year.

The catalog has three sections: 1. "Catalogs of Industrial Equipment, Materials, and Supplies," arranged alphabetically by names of companies, contains illustrated descriptions of the products manufactured by the companies represented in the book. 2. "Manufacturers List," an alphabetical list of firms included in the issue, giving addresses, products manufactured and a brief historical statement about the concerns presenting catalogs. 3. "Classified Index to Manufacturers" contains the names of 700 firms, and lists, under 4000 classifications, thousands of items used by industry. It is also an index to the descriptions of the specific products provided by the advertisers in the catalogs that comprise this section of the book.

Standards for Rating and Testing Air-Conditioning Equipment

THE Air Conditioning Manufacturers' Association, formed some eighteen months ago, has been gathering data and formulating bases for the establishment of standards for the guidance of manufacturers and users of air-conditioning equipment. The first of these standards has been practically completed for submission to the association as the recommendation of the joint committee on Rating Commercial Refrigerating Equipment, composed of representatives of the American Society of Refrigerating Engineers, National Electrical Manufacturers Association, Refrigerating Machinery Association, American Society of Heating and Ventilating Engineers, and Air Conditioning Manufacturers' Association. This joint committee has recommended "Proposed Standards for the Rating and Testing of Air-Conditioning Equipment." The Air Conditioning Manufacturers' Association is located at 915 Southern Building, Washington, D. C.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after November 25, 1935, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

New Applications

BLANCHARD, E. PAYSON, Bridgeport, Conn.
BLATZ, GEO. H., Brooklyn, N. Y. (Rt)
BOWERMAN, MYRON R., Homeworth, Ohio (Rt & T)
COZZO, S. E., Richmond, Calif.
DOREMUS, GEO. A., Brooklyn, N. Y.
DVORAK, J., Houston, Tex.
ECKSTROM, ALBERT W., Mt. Jewett, Pa.
EFFROSS, MAX P., New York, N. Y.
EVANS, ROBT. G., Seattle, Wash.
FARRIS, DEAN MARSHALL E., Albuquerque, N. M. (Rt & T)
FRECKER, HARRY M., Passaic, N. J.
FREEMAN, G. F., San Francisco, Calif.
GARRETT, ROY M., Sheboygan, Wis.
GORDON, JOHN D., Kansas City, Mo.
HANNY, RUPERT M., Ridley Park, Pa.
HENKEL, LOUIS C., Hanford, Calif.
HEROUX, LEO H., N. Plainfield, N. J.
HODGES, KENNETH R., Iowa City, Iowa (Re)
HOTTEL, PROF. H. C., Cambridge, Mass.
HUFFMAN, C. WARREN, Huntington Park, Calif.
MIDGETTE, E. L., Buffalo, N. Y. (Re)
NORRIS, ROLLIN HOSMER, Scotia, N. Y.
PALAFOX, ROSENDO M., New York, N. Y.
PARKER, EDWIN ELLISON, Schenectady, N. Y.
PRIOR, JOHN EDW., Kearny, N. J.
SOLOV, H. H., Brooklyn, N. Y.
STADTHERR, NICHOLAS G., Minneapolis, Minn.
STEWART, RANDALL E., Hawthorne, N. J.
THOREN, THEO. R., Iowa City, Ia.
WILLIAMS, H. G., Chicago, Ill.
YANAGIHARA, CAPT. H., New York, N. Y.

Change of Grading

Transfers from Junior

ANDREW, LOWELL R., St. Louis, Mo.
CARMICHAEL, PROF. COLIN, Chapel Hill, N. C.
CASSIDY, T. FRANK, JR., Hartford, Conn.
COBERLY, C. J., Huntington Park, Calif.
CRAIN, HENRY L., Kansas City, Mo.
DOELLING, H. A., Mountain Lakes, N. J.
EBAUGH, PROF. NEWTON C., Gainesville, Fla.
FRAME, W. M., Ambridge, Pa.
GIVENS, HOMER CHAS., Lucien, Okla.
HARGEST, WM. J., Brooklyn, N. Y.
REED, FREDERICK J., Durham, N. C.
RICK, CONSTANTINE, West Allis, Wis.
SCHNEIDER, MILTON LOUIS, New York, N. Y.
SCHWARTZ, FRANK L., Brooklyn, N. Y.
SIGMON, ARVIL C., Dayton, Ohio

Necrology

THE following deaths of members have recently been reported to the Office of the Society:

ATTERBURY, WILLIAM WALLACE, September 20, 1935
BURGHAM, MAURICE L., July 19, 1935
BUZBY, ARTHUR D., May 26, 1935
CARPENTER, LOUIS G., September 12, 1935
CHRISTOPHERSON, MARTIN H., September 9, 1935
JABLOW, CHARLES, September 12, 1935
JUNGGREN, OSCAR, September 24, 1935
KILGOUR, DWIGHT F., September 10, 1935
LIETZ, ADOLPH, June 17, 1935
NEWLIN, HENRY S., September 16, 1935
SCHUTTLER, CARL H., July 28, 1935
STORMS, FRANK F., June 2, 1935
THORNTON, WILLIAM M., September 11, 1935
TUCKER, JAMES C., August 31, 1935

A.S.M.E. Transactions for October, 1935

THE October, 1935, issue of the Transactions of the A.S.M.E., contains the following papers:

The Design and Performance of a High-Pressure Axial-Flow Fan (AER-57-1), by L. S. Marks and Thomas Flint

Reliability of Aircraft Welds (AER-57-2), by N. F. Ward

The Viscosity of Water and Superheated Steam (FSP-57-11), by G. A. Hawkins, H. L. Solberg, and A. A. Potter

Stresses in Three-Dimensional Pipe Bends (FSP-57-12), by William Hovgaard

An Airfoil-Type Propeller Blower for Ventilating Electrical Machines (FSP-57-13), by C. E. Peck and M. D. Ross

Progress Report on Cavitation Research at Massachusetts Institute of Technology (HYD-57-11), by J. C. Hunsaker

Progress in Cavitation Research at Princeton University (HYD-57-12), by L. F. Moody and A. E. Sorenson

The Measurement of Air Flow in Fan Inlet and Discharge Ducts (PTC-57-1), by L. S. Marks

The Definition of the Quantity-Head Characteristics of Fans (PTC-57-2), by M. C. Stuart and W. E. Somers

Drying Problems of the Ceramic Industry (PRO-57-3), by J. L. Carruthers

Discussion

On previously published paper by G. M. Bartlett and A. Egli

For closing dates on discussion, see footnote on first page of each paper.